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GEOMETRY ROUTINES FOR USE IN THE TIMOC CODE

by

R.J. JAARSMA and H. KSCHWENDT

1970

Joint Nuclear Research Centre
Ispra Establishment - Italy

Reactor Physics Department
Reactor Theory and Analysis

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ABSTRACT

For application in the Monte Carlo Code TIMOC a number of subroutines describing different geometrical configurations have been developed. Their description is collected in this report. The first three subroutines of this report were made a long time ago for special purposes and describe such simple geometries as cylinders, slabs and spheres, as well as more complicated configurations like concentric rings, ring sectors, lattices of cylinders or spheres. A complete description of the problems which can be handled, the way of linking to the main programme and the preparation of the input data are given. The last article in this report deals with the adaptation of the subroutine GEOM of the O5R code, a more general geometry subroutine, to the TIMOC code. Only the way of linking has been explained, other information must be taken from the O5R report.

KEYWORDS

GEOMETRY
MATHEMATICS
MONTE CARLO METHOD
CONFIGURATION
CYLINDERS
SPHERES
LATTICES
RESEARCH REACTORS
COMPUTER
DIGITAL SYSTEMS

Table of Contents

GEOM (O5R)

GEOMETRY ROUTINES FOR USE IN THE TIMOC CODE *)

Introduction

The geometry routines used by the Monte Carlo Code TIMOC have more or less an independent character. The descriptions made of them are collected in this report under the following titles:

SORSEC (R.J. Jaarsma) - Describes a cylindrical system and has been developed to simulate the proposed Euratom pulsed fast reactor SORA.

GSPHER (H. Kschwendt) - Describes a system of concentric spheres.

SLBCYL (R.J. Jaarsma) - Describes a system of infinite slabs or a system of infinite concentric cylinders in a rectangular lattice.

GEOM (R.J. Jaarsma) - Describes the adaptation of the O5R-GEOM routine for the use in the TIMOC code.

This report contains 3 independent routines. The summary in the beginning of the description of each routine gives in short moreinformation.

For each of the routines an exposition of the problems it may deal with and a user's manual is given. The most extensive description is given of SORSEC, sometimes a reference has been made to this in the description of the other routines. In this report the parameters are named with the names used in the programs. As the routines have been developed separately from each other, the same parameters may sometimes not have the same name in the different routines, while it also may happen that a name is not covering the same parameter in each routine. However all parameters are defined explicitly in each of the three descriptions.

The routines are written in the FAP language for the IBM 7090 computer. They were tested carefully and used many times in practice for different configurations.

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*) Manuscript received on 28 July 1970

At a late stage in our work, we received the O5R code and started to use its geometry part in the TIMOC code. The way we did it is described in the last article. The problems this subroutine deals with and the input preparation can be found in the O5R report.

SORSEC - A Geometry Routine for SORA Type Reactors

R.J. Jaarsma

Summary

The geometry routine, described here, has been designed in order to make possible the application of the Monte Carlo Method to a very detailed model of the proposed Euratom fast pulsed reactor SORA. The first version of the routine was made by W. MATTHES [1]. It has been improved and developed into the present version by the author.

The main feature of the geometry routine is that it calculates, for a neutron with a given starting point, direction and flight path, a collision or crossing point in a 3-dimensional configuration. By crossing point is meant the point at which the neutron enters another geometrical region of the assembly. The basic assembly consists of one or more concentric cylinders, each of which can be cut, if required, into several rings. These rings can be subdivided yet further into sectors, giving, when necessary, a very detailed heterogeneity.

In addition this cylindrical assembly can be truncated by a plane parallel to the axis of the cylinders, the resulting secant plane being termed "the window". In combination with this window, a special prisma, called "the bridge", may be inserted in such a way that the rectangular ground or upper plane is in the window and the rest of the bridge is surrounded by the parts of the cylinders. Fig. 2 and 3 make this clear. In front of the window one may put one or two slabs, with the planes parallel to the axes of the coordinate system, each consisting of 1, 3 or 5 symmetrical parts (fig. 4).

The programme can be made to select different combinations of the above geometries, according to needs of a particular problem, by varying appropriate parameters. The above geometrical options were concieved with special reference to the SORA reactor.

The calculation times associated with the programme (which is written in FAP for the IBM 7090 computer) have been minimized as much as possible at present.

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1) described in an internal report

1) Geometry

The rectangular coordinate system is defined so that the axis of the concentric cylinders is the z-axis and, if there is a window, the front plane of this is parallel to the z-axis and normal to the y-axis; the positive y-axis goes through the center of the window and bridge.

The geometrical regions are defined in the following way: The cylinders by their radii; the planes, which cut the cylindrical shells in rings, by their z-coordinates; the sector walls in a ring by the anticlockwise angle with the positive y-axis; the window by the y-coordinate; the bridge by the y-coordinate of the back plane, width of the front and back plane and height; the slabs by their center and dimensions (the planes of the slabs are assumed to be parallel to the axes of the cylindrical system).

The cylindrical system (inclusive of the bridge, if there is one) and slab 1 and 2 may not touch each other i.e. all three must be separated by gaps. The y-coordinates of all parts of slab 2 must be greater than the y-coordinates of all parts of slab 1. The bridge may not project outside the outmost cylinder. Allowance is made for the free leakage of neutrons at the extreme boundaries of the system. Regions into which neutrons leak without returning or where they are totally absorbed are allotted the material number (region index) zero. In this connection the surroundings have been divided into three parts: The part in front of the window, surrounding the slabs and called the "space"; the extensions to the cylinders at the top and at the bottom (which are viewed as one region = subregion 0) and the environment around the outermost cylinder. The last part is by definition always a leakage region (when a neutron enters this region the material number is set equal 0). This leakage zone can be displaced outwards by introducing a dummy vacuum zone. This will be necessary, for example, if the slabs are wide with respect to the cylinders or if they are in an extremely asymmetric position. The media in the other two parts are defined by their material number in the input data. If a neutron is in the "space" and it is assumed that $\Sigma_t = 0$ and the direction of the neutron does not intersect the window or slabs, then it is assumed that the neutron is lost by leakage. This information is transmitted to the main programme by setting the actual material number equal to zero.

The geometrical regions are identified in the following way:

Main region:

Shells from inside to outside are numbered 1 to M.
The "space" is taken as main region M+1 (= L).
The bridge is main region L+1.
Slab 1 (nearest to the window) is main region L+2.
Slab 2 is main region L+3.

Subregions:

a) In the shells subregion 0 is the part above and below the cylindrical regions. It extends to infinity in both directions. The rings are numbered from the bottom to the top by 1,2,...

Note: The number of rings is equal in each shell and is therefore defined by the shell with the most rings. Therefore one has to add dummy rings of zero hight in those shells, which contain less rings. These dummy rings must be at the bottom.

b) In the slabs subregion 0 is the center part. Subregions 1 are the two symmetrical parts on both sides of subregion 0, subregions 2 the next two symmetrical parts. The symmetry is with respect to the plane of the system parallel to the y-z plane through the center of the slab.

Sector regions:

They exist only in the rings. Starting on the positive y-axis and going in the anticlockwise direction, they are numbered 1,2, etc. The sector part between the last sector and the positive y-axis belongs automatically to sector 1.

Limits:

Only the rings of the 8 innermost cylindrical shells may have sectors. The maximum number of rings per shell is 19 in the standard version of the programme. Users familiar with the FAP language may be able to increase this number by modifying the appropriate DUP-pseudo operations

in the BCD-deck and making a new assembly. The number of cylinders and sectors is only limited by the storage available in the computer.

Error messages:

In consequence of rounding errors, it may happen that when the flight path of a neutron exactly or nearly intersects with the z-axis of the system, the square of the distance of these two lines becomes negative. This square is an intermediate result. In such a case the square of the distances is set equal 0 and a message mentioning the negative value is printed.

Another consequence of inaccuracy is that sporadically the x, y, z coordinates are not consistent with the geometrical region parameters. In such a case the neutron becomes lost by leakage (RGM = 0) and the following message will be printed:

EXTC. Z = ..., Y = ..., X = ..., ARG = ..., RG = ...

2) Calculations

The central part of the geometry programme is the routine with the entry GPATH . This part calculates the crossing point with the boundary of the actual geometrical region or a collision point in this region. The distance S to the boundary (in cm) along the flight path of the neutron is always calculated (see appendix 2). By λ we denote the random variable to select the neutron flight path between collisions (λ = number of mean free paths between 2 collisions). If S is equal to or less than the flight path, λ/Σ_t, the neutron is assumed to leave the region, the crossing point is calculated and the number of mean free paths, λ, is decreased by $S \cdot \Sigma_t$. Otherwise a collision occurs before the boundary, the length of the flight path is λ/Σ_t and the collision point is calculated. The part of the routine with the entry GSTRT calculates random starting points in indicated geometrical zones (see appendix 3).

See section 5 for further information.

3) Communication with the RWS main programme

A set of parameters, whose values at any time suffice to completely characterize the neutron, is stored in the COMMON part, with the following notation (I = integer, F = floating point number):

RGM: Material number (in TIMOC called region index) in the actual geom. region. (I)
RG: Geometrical main region number. (I)
ARG: Geometrical subregion number. (I)

X:
Y:
Z:
} Rectangular space coordinates, giving position of the neutron. (F)

SINP:
CØSP:
SINT:
CØST:
} Defining φ and Θ, being the spherical coordinates for the direction vector (Fig. 5). (F)

SGT: Total cross-section of material RGM. (F)
MFP: Number of mean free paths in the flight path of the neutron. (F)

FPATH: Length of flight path to next collision point in cm. (F)
PTHX: Length of flight path to a crossing point in cm. (F)

NRG: No meaning.

QRET:
QØUT:
} Used for special feature. See explanations.

SEKN:
BLR:
} Special parameters. See explanations.

QSTPT: If $\neq 0$, fixed start point of primary neutrons.
QTIME: See explanations.

QCØLL:
QBLØC:
No meaning.

SRG: Geometrical sector region number. (I)

4) Remarks and Explanations

a) RGM is stored in the decrement part of the address.
RGM = 0: by definition equal to leakage (total absorption).

b) The input parameter RØUT is a decimal number of the format xxxyy. The decimal digits yy are stored in location RØUTP. If a neutron crosses a boundary, RØUTP determines QRET and QØUT as follows:

QØUT = 1 if RØUTP = 0 and RG = L, L+2, L+3;
QØUT = 1 if RØUTP ≠ 0 and RGM = RØUTP;
QØUT = 0 in the other cases.

QRET = 1 if RØUTP = 0, QØUT = 0 and the neutron is crossing the window from outside;
QRET = 1 if RØUTP ≠ 0 and RØUTP is equal to the material number in the zone which the neutron is leaving. For QOUT the 1 is in the TAG-part, for QRET the 1 is in the last bit.

c) The decimal digits xxx of RØUT (see b) are stored in the location RØUTQ and may serve another purpose if they are made unequal to zero. They may be used to set $\Sigma_t = 0$ if the neutron enters one of the slab zones specified as follows:

RØUTQ:	ZØNE:
210	Positive part of subregion 1 in slab 2
-210	Negative " " " 1 " " 2
220	Positive " " " 2 " " 2
-220	Negative " " " 2 " " 2
110	Positive " " " 1 " " 1
-110	Negative " " " 1 " " 1
120	Positive " " " 2 " " 1
-120	Negative " " " 2 " " 1

By means of this facility, the user may consider unsymmetrical slabs. For the meaning of "positive part" and "negative part", see (e) below.

d) SEKN should be ≠ 0 at the starting point of a neutron history.

e) BLR is a position parameter (floating point) if the neutron is in a slab. BLR = -1 means that the neutron is in the negative part of the slab (with respect to the center of the slab and the direction of the x-axis). BLR = 1 means that the neutron is in the positive part of the slab.

f) If QTIME $\neq$ 0 then the data for printing are not only written on the normal output tape, but also once on the tape of unit B 6.

5) Entries

All parts of the routine must be entered by a TRA entry name, 4.

GREAD. This part reads all input data. It calculates volumes and surfaces and developes and prepares the data in such a way that it can be handled quickly. GREAD, which can be executed only once, is the last part of the programme deck; between this part and the rest of the programme the data is placed. The return transfer is to the first location after the calling instruction, while the accumulator contains the first free location after the data. The input data are partly tested. Illogical data may lead to a stop in the execution phase.

GPRNT. This part prints all input data and the calculated volumes and window surfaces of the geometrical regions. To obtain a tidy print-out, the routine searches, on entry, into the accumulator where the number of lines already printed on the actual page is stored. On exit, the position of the last printed line is preserved so that the next printing sequence can be similarly treated. See 4f.

GSTRT. This subroutine calculates a random starting point in the given geometrical region(s). It sets the parameters RGM, RG, ARG, X, Y, Z, BLR and SRG. If QSTPT $\neq$ 0, only the parameters RGM, RG, ARG, BLR and SRG are set. In both cases the return transfer is to the first location after the calling instruction, while the accumulator contains the parameter RGM (in the decrement part).

GPATH. This part calculates a crossing or collision point of the neutron, On entrance, the parameters RGM, RG, ARG, X, Y, Z, SINP, CØSP, SINT, CØST, SGT, MFP, SRG should have a consistent meaning. If it is entered with a new neutron (that means a neutron with a position which is not calculated by GPATH) then SEKN should also be $\neq$ 0. SEKN is set equal to zero by GPATH.

In the case of a crossing into another geometrical region, the return transfer into the main programme is to the second location after the calling instruction. The following parameters are always replaced by their new values: RGM, RG, ARG, X, Y, Z, MFP, SRG.

Eventually SGT (see 4c), QRET and QØUT (see 4b), BLR (see 4e), are also replaced.

FPATH = 0.
PTHX is the flight path, which the neutron just has covered to the crossing point.

In the case of a collision, the return transfer into the main programme is to the first location after the calling instruction. The following parameters are always replaced by their new value: X, Y, Z.

FPATH is the flight path which the neutron just has covered to the collision point.
PTHX = 0.

If the neutron is in the "space" and lost by leakage then RGM, FPATH and PTHX are all set equal to zero and the return transfer is the same as in the case of crossing.

CELL. This part provides the transfer of the material volumes. When entered, the required material number should be in the accumulator (address part). The return is to the first location after the calling instruction, while the accumulator contains the total volume of all geometrical regions filled with the material in question.

SURFC. This part provides the transfer of the window surface area corresponding to a given material number. It is used in the same way as CELL. An extra feature is that the MQ-register contains the floating point representation of the material number.

PRØJ. This part gives information about the projection of the direction vector on the y-axis ($\perp$ window) when a neutron passes through the window.

The return is to the first location after the calling instruction if the neutron did not just cross the window and to the third location if the neutron just made a crossing with the window. In the last case the accumulator contains the projection and the MQ-register contains the number, either of the material just left if the projection is positive or of the material just entered if the projection is negative.

END. This is a dummy entry for knowing the last programme location.

NAME. Also a dummy entry, where the name SØRSEC is stored.

GINP, GEPR, BVTBF, GERJ, GEDS, GMAC are dummy entries without meaning.

The following subroutines must be added:

a) WPKO6 and WPKO7 for in- and output.
b) SQR3 Square root routine.
c) RNFL and RCØS for generating floating point random numbers and random cosines and sines.

6) Input SORA Geometry Programme - SØRSEC

The data are read by WPKO6.

FØRMAT: column 8-10: DEC. The decimal data start in column 12 and end in column 72. Successive words of data on a card are separated by commas, and the first blank to the right of column 12 indicates that all punching to the right of this blank is irrelevant.

The input data are partly tested by the programme. The final check must be done by the user by means of the print of the data. Illogical input data may give a stop in execution.

I = integer, F = floating point number.
Units: Length in cm. Angles in radians.

Card 1 GENERAL (I):

RØUT,CTR,CSW,CNB,CNR,L,NBARG

RØUT is a combination of parameter RØUTQ and RØUTP. See 4c and 4b

CTR = 2 Assembly without any sector region.
3 Assembly with at least 2 sectors.

CSW = 0 No window present.
1 Window
2 Window + bridge

CNB = 0 No slabs
1 One slab
2 Two slabs

CNR = ab, where a = number of subregions in slab 2 (0,1,2 or 3) and b = number of subregions in slab 1 (0,1,2 or 3). Take as slab 1, the slab nearest to the window.

L = M+1, where M is the number of concentric shells.

NBARG = number of rings per shell. NBARG is by definition equal for all the cylinders and must be equal or greater than the the number of subregions minus one in any of the slabs.

Card 2 WINDØW AND BRIDGE (F):

YB,YL,BF,BB,WH

This card (5 numbers) has to be here completely, also in the case where CSW = 0 or 1. The use of this data is governed by CSW. See fig. 3 for the meaning of the parameters.

Card 3 SLAB 1(F):

WXE,WYE,WZE,BGE,BME,BWE,BYE,BZE

WXE: x-coordinate)
WYE: y-coordinate) of the center of slab 1.
WZE: z-coordinate)

See fig. 4 for the meaning of the other five parameters.

This card (8 numbers) has to be here completely, also in the case where CNB = 0.

Card 4 SLAB 2(F):

WXZ,WYZ,WZZ,BGZ,BMZ,BWZ,BYZ,BZZ

See slab 1 (card 3).

This card (8 numbers) has to be here completely, also in the case where CNB = 0 or 1.

The use of data given by card 3 and 4 is governed by CNB.

Card(s) 5 RADII (F):

$R_M, R_{M-1}, \ldots, R_1, 0$

R_M is the radius of the outer cylinder.

Number of data is L. See fig. 2.

Card(s) 6 Z-COORDINATES OF THE HØRIZONTAL PLANES, WHICH DIVIDE THE SHELLS IN RINGS (F).

$HE_{M,0}, HE_{M-1,0} \ldots HE_{1,0}, HE_{M,1}, HE_{M-1,1} \ldots HE_{1,1} \ldots HE_{1,NBARG}$

M = number outmost cylinder, M = L-1

$HE_{M,0}$ = Z-coordinate of the bottom of the lowest ring (subregion 1) in the outer cylindrical shell.

$HE_{m,k}$ = Z-coordinate of the upper plane of subregion k in cylindrical shell m.

Number of data is M*(NBARG+1)

Always $HE_{m,k+1} \geqslant HE_{m,k}$. See fig. 2

Note: If there are less than NBARG rings in a cylindrical shell, then one has to make the low numbered ring 0 cm high and therefore to take for $HE_{m,1}$ etc. the value of $HE_{m,o}$ and so on.

Card(s) 7 NUMBER ØF SECTØRS IN THE RINGS.(I).

$NBS_{M,0}, NBS_{M-1,0} \ldots NBS_{M,1}, NBS_{M-1,1} \ldots NBS_{1,1}, \ldots NBS_{1,NBARG}$

This data should be given if CTR = 3.

If there are no sectors in a ring: NBS = 0.

$NBS_{m,o}$ (m running from M to 1) gives NBS for the space underneath and above the reactor (subregion 0). In general the NBS = 0 on this place.

Number of data is M*(NBARG+1).

Card(s) 8 ANGLES, WHICH FØRM THE SECTORS (RADIANS):

$\beta_{I,m,k}, \beta_{I-1,m,k}, \ldots \beta_{1,m,k}$ etc.

Only if there are sectors. I = $NBS_{m,k}$

$\beta_{i,m,k}$ is the anticlockwise angle between the positive y-axis and the left side (looking from the center) of the sector number i in shell m and in ring k. The total number of β's is equal to the sum of the numbers given in card(s) 7.

The order of input $\beta_{i,m,k}$ is

k starting with the lowest value and increasing
m " " " greatest value and decreasing
i running from $NBS_{m,k}$ to 1
i is varying most rapidly
k is varying least rapidly.

Card(s) 9 TRA 3,4

Card(s) 10 MATERIAL NUMBERS IN THE SUBREGIONS (I):

$MAT_{J,0}, MAT_{J-1,0}, MAT_{J-2,0}, MAT_{J-3,0}, MAT_{M,0}, \ldots MAT_{1,0}$

$MAT_{J,1}, MAT_{J-1,1}, 0, 0, MAT_{M,1}, \ldots . \quad MAT_{1,1}$

$MAT_{J,2}, MAT_{J-1,2}, 0, 0, MAT_{M,2}, \ldots . \quad MAT_{1,2}$

$0 \ , \ 0 \ , \ 0 \ , \ 0, \ MAT_{M,3}, \ldots . \quad MAT_{1,3}$

.....

$0 \ , \ 0 \ , \ 0 \ , \ 0, \ MAT_{M,NBARG} \quad MAT_{1,NBARG}$

J = M+4

$MAT_{J,0}$ = material no. subr. 0 of slab 2
$MAT_{J-1,0}$ = " " " 0 " " 1
$MAT_{J-2,0}$ = " " bridge
$MAT_{J-3,0}$ = " " space

The order of the material numbers in the subregions is almost the same as in card 6, except that the material numbers for the slabs, bridge and "space" are also given. Where there exist no subregions of these regions a dummy number (e.g. 0) must be put. The same is necessary for a ring wi sectors in it. In the cylindrical shells the subregion 0 refers to the e tension under and above the shells, so that, for example, $MAT_{1,0}$ is the medium under and above the inner cylinder. In general one will put here 0 to create an outer boundary where the neutron escapes from the system. The material numbers are defined in the TIMOC-main programme where they are called Region Indices.

Card(s) 11 MATERIAL NUMBERS IN THE SECTORS (I):

$MAT_{I,m,k}, MAT_{I-1,m,k} \ldots MAT_{1,m,k}$ etc.

The material numbers are in the same order as the angles in card(s) 8. There is a one-one correspondence. The sector is at the right side (looking from the center) of the corresponding angle ß.

Card 12 TRA 3,4

Card 13 GEOMETRICAL STARTREGIONS (I):

NBSTA,XXYYZZ,...

NBSTA = number of start regions
Each start region is defined by a decimal number of the format XXYYZZ which is interpreted as follows:

XX = sector region
YY = region. 1 till M if in cyl. shell

M+1 = space (only if fixed starting point)
M+2 = bridge
M+3 = slab 1
M+4 = slab 2

ZZ = subregion

Card 14 TRA 3,4.

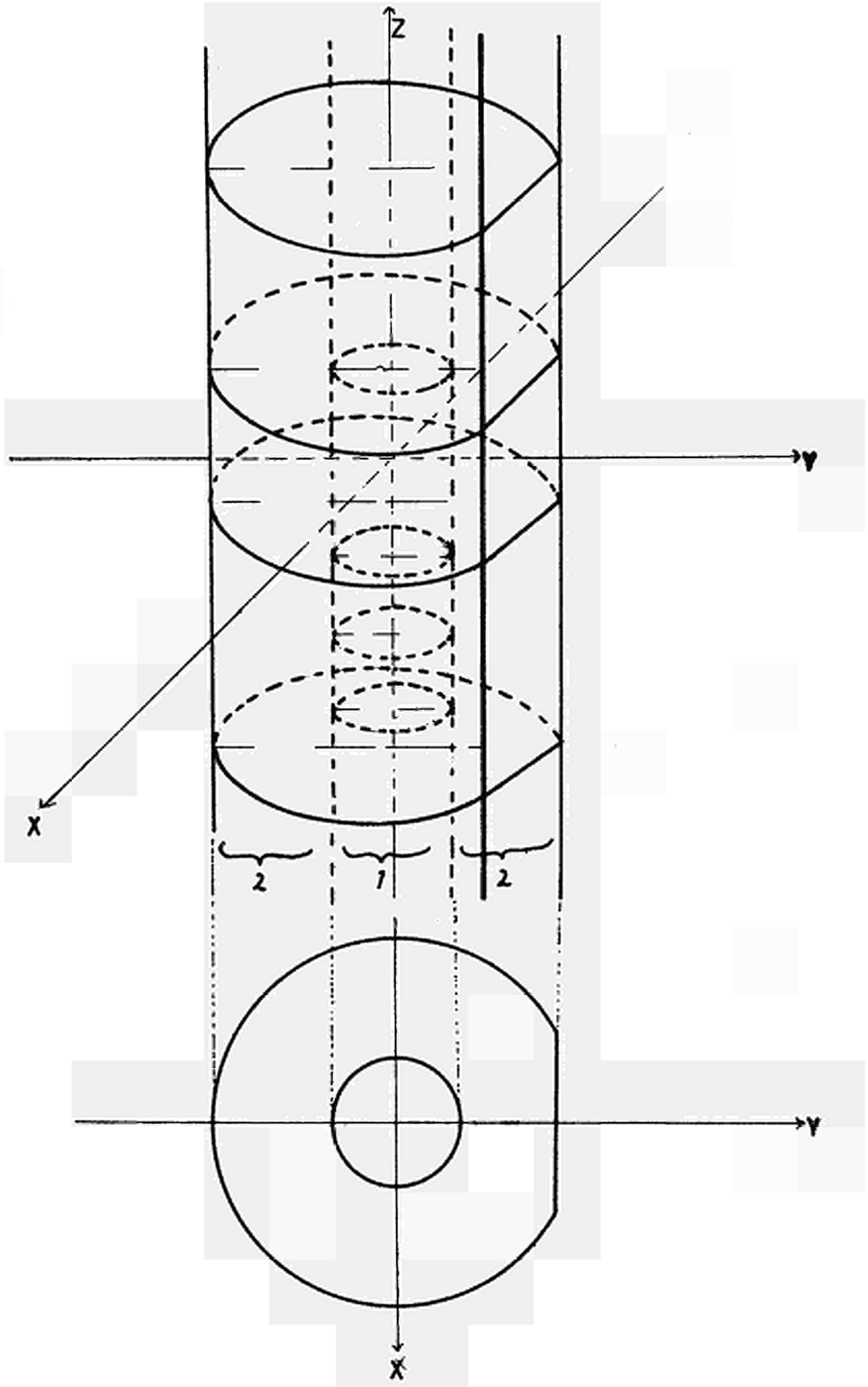


Fig. 1 Two cylindrical regions, outer one truncated to form a window. Region 1 consists of 3 cylinders, region 2 of 3 rings.

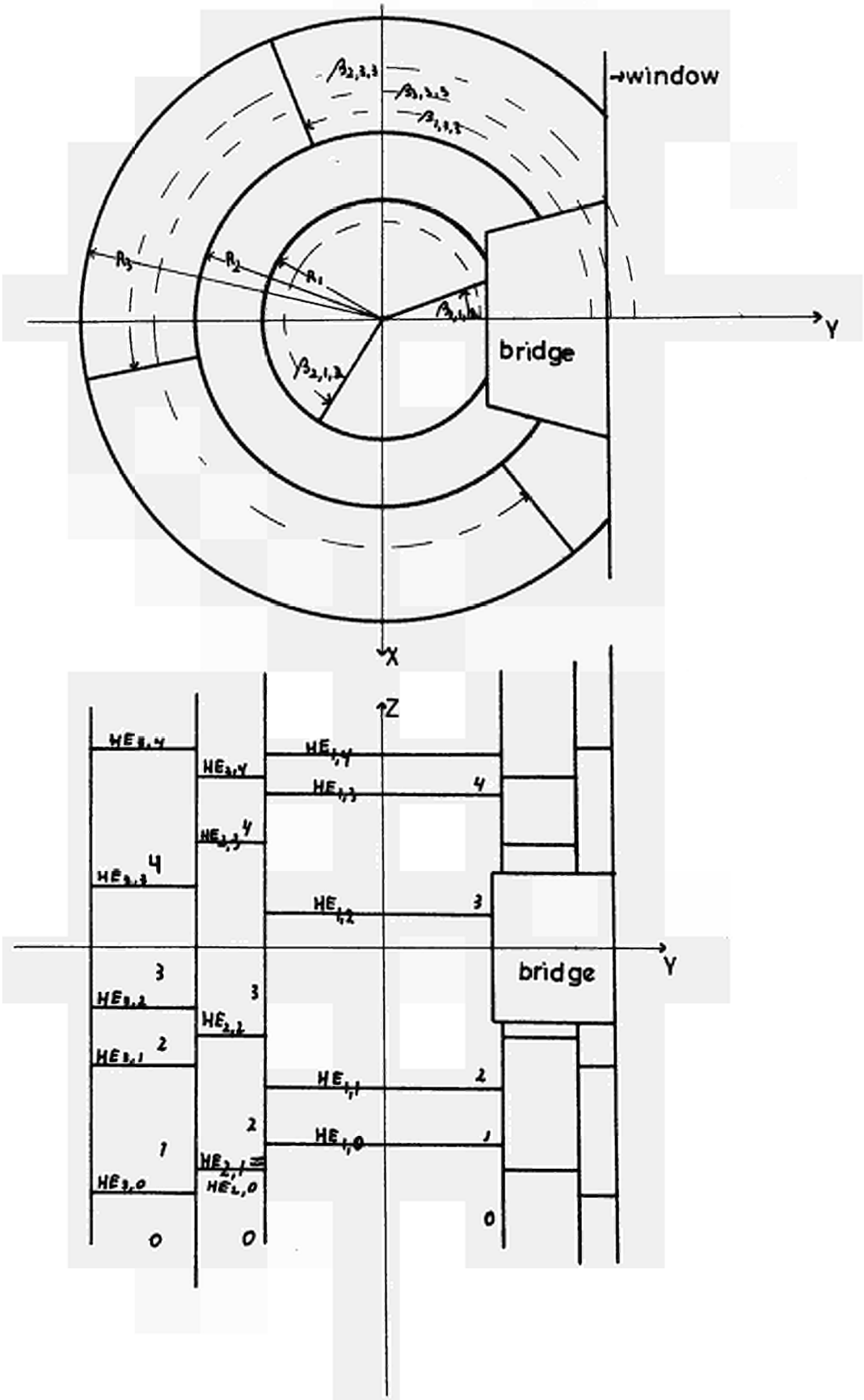


Fig. 2 Cross sections at X,Y and Y,Z plane of a mock-up of 3 shells with window and bridge. Subregion 2 in the inner cylinder is divided in 2 sectors, subregion 3 in the outer shell in 3 sectors.

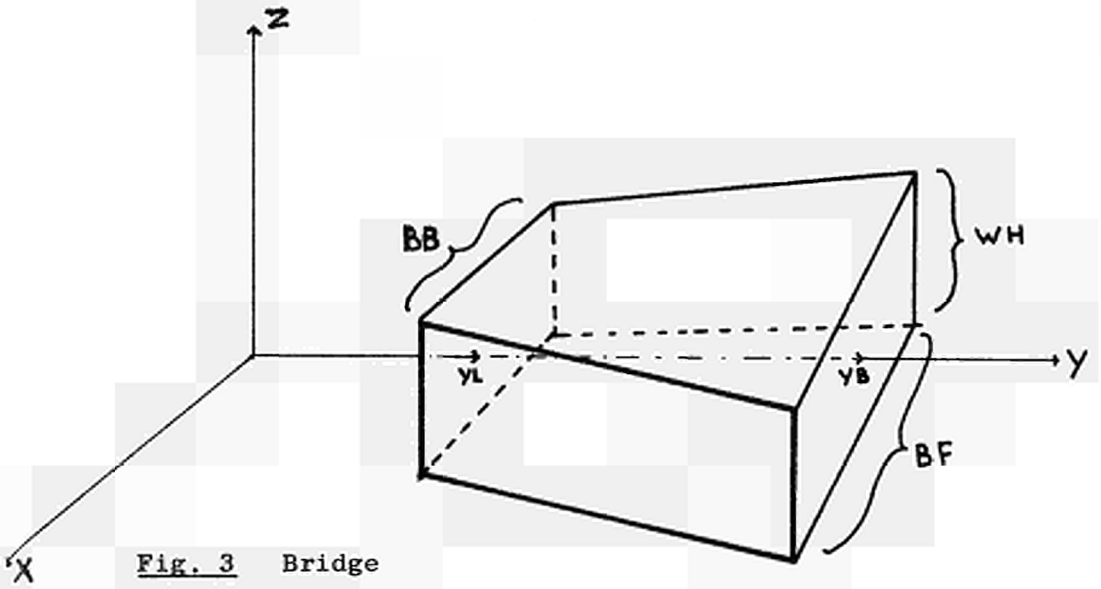


Fig. 3 Bridge

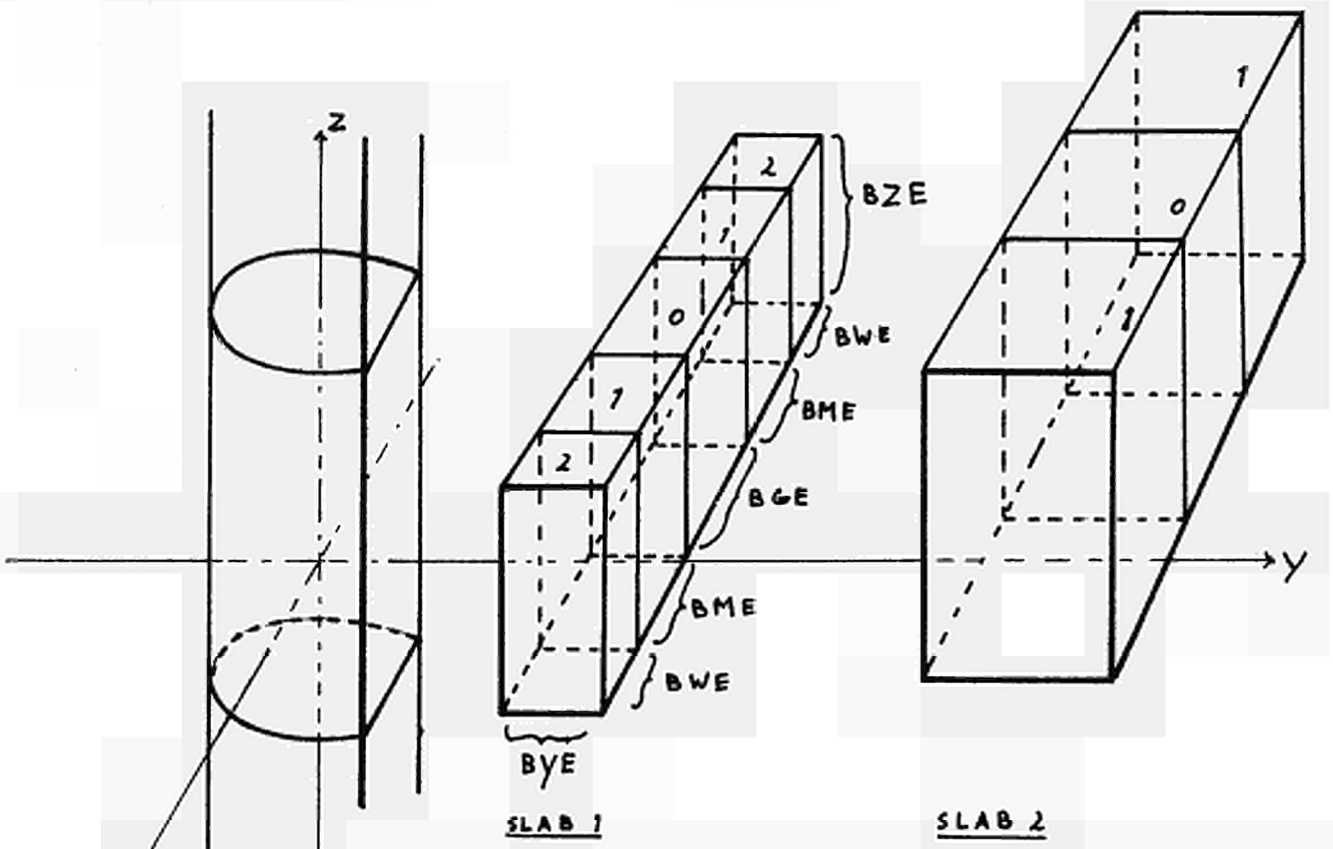


Fig. 4 Reactor with two slabs. Slab 1 consist of subregion 0, two symmetrical subregions 1 and two symmetrical subregions 2.

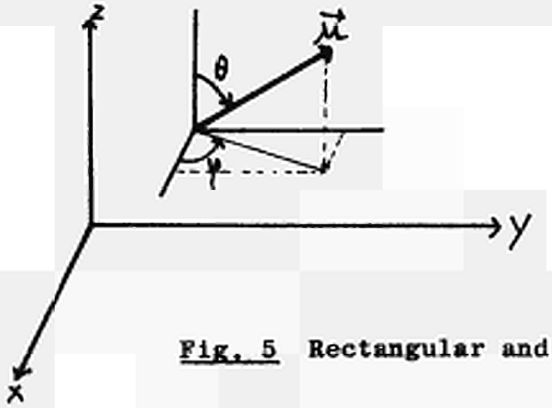


Fig. 5 Rectangular and spherical system.

APPENDIX 1

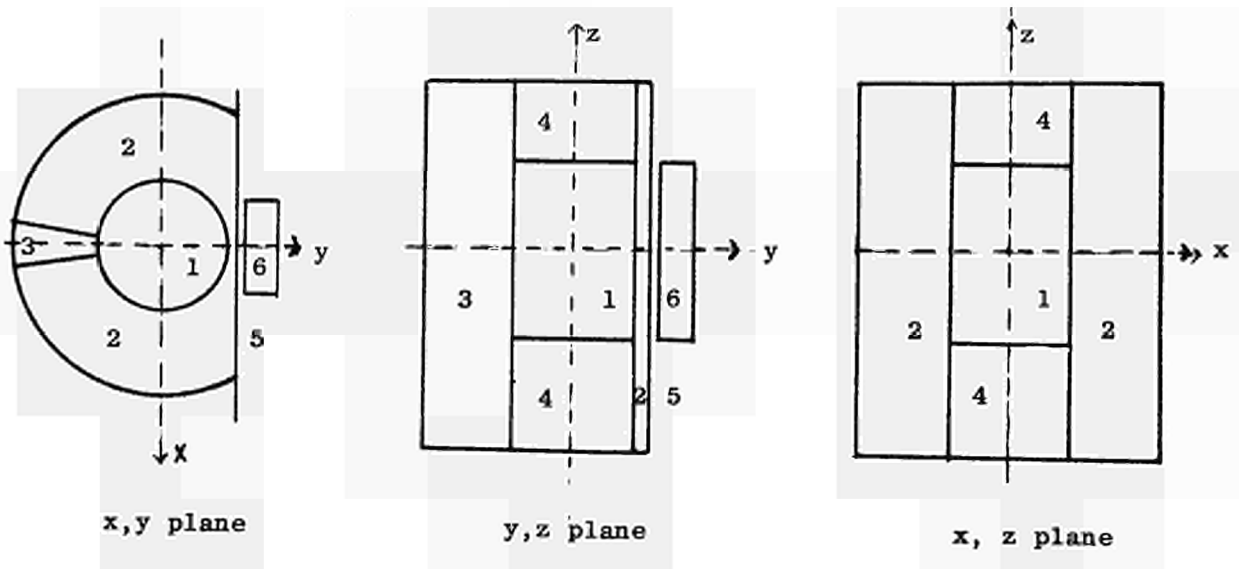
An example of the preparation of the input data for SØRSEC

Consider an assembly of two concentric cylinders with radii of 8 cm and 20 cm respectively and a common height of 49 cm. Assume that the central cylinder is divided into three parts, the bottom, central and upper part being of 15, 24 and 10 cm height respectively. Imagine that the outer cylindrical sleeve is cut by a segment of 20°. (One may think of a system in which a segment of the reflector has been removed.)

In order to fully exemplify the use of SØRSEC, we truncate the outer cylinder at a distance of 10 cm from the center on the side opposite to the omitted sector. In front of the truncation plane, at a distance of 1 cm, a slab of 5 cm thickness is placed. The other dimensions of the slab are 12 cm (width) and 24 cm (height). The innermost cylinder will be the starting region. On page 23 and 24 is given a listing of the input cards and a print-out of the input data.

The material numbers (region indices) must be defined by the main programme (TIMOC code) and will be, for example, as follows:

1 is fission material,
2, 4 and 6 is reflector material,
3 and 5 is void,
0 is by definition equal to leakage (total absorption).



x,y plane y,z plane x, z plane

Cross sections of the example

AN EXAMPLE OF THE PREPARATION OF THE INPUT DATA FOR SNRSEC

PROBLEM | DATE | PAGE | OF

```
DEC  0,3,1,1,1,3,3                                          GENERAL          1A
     10.0,0,0,0,0,0                                         WINDOW           2A
     0,13.5,0,12.0,0,0,5.0,24.0                             SLAB 1           3A
     0,0,0,0,0,0,0,0                                        SLAB 2           4A
     20.0,8.0,0                                             RADII            5A
     -27.0,-27.0                                            Z-COORDINA-      6A
     -27.0,-12.0                                            TES OF THE       6B
     -27.0,12.0                                             HORIZONTAL       6C
     +22.0,22.0                                             PLANES           6D
     0,0,0,0,0,0,0,2,0                                      NB. OF SECTORS   7A
     3.31613,2.96706                                        ANGLES           8A
                                                                             9A
TRA  3,4
DEC  0,6,0,5,0,0                                            MATERIAL NB.     10A
     0,0,0,0,0,4                                            OF THE SUB-      10B
     0,0,0,0,0,1                                            REGIONS          10C
     0,0,0,0,0,4                                                             10D
     3,2                                                    SECT. MATERIAL   11A
TRA  3,4                                                                     12A
DEC  1,102                                                  STARTREGION      13A
TRA  3,4                                                                     14A
```

DATA FOR SORA GEOMETRY

MATRNB	QRET	SECTOR	REACTOR	PLANE	WINDOW	ONE	BLOCK	BLOCKREG.	NB. OF CONC. SHELLS	NB. OF HOR. REGIONS
0		3		1		1		1	3-1	3

WINDOW ** FRONT-COORD.= 10.000, BACK-COORD.= 0. , WIDTH-FRONTS.= 0. , WIDTH-BACKS.= 0. , HEIGHT= 0.

FIRST BLOCK, MIDPOINT COORDINATES, * X1 = 0. , Y1 = 13.500, Z1 = 0.
THICKNESS ** SUBRG. 0 = 12.000, SUBRG. 1 = 0. , SUBRG. 2 = 0. , Y-WIDTH = 5.000, Z-WIDTH = 24.000

SECOND BLOCK, MIDPOINT COORDINATES, * X2 = 0. , Y2 = 0. , Z2 0.
THICKNESS ** SUBRG. 0 = 0. , SUBRG. 1 = 0. , SUBRG. 2 = 0. , Y-WIDTH = 0. , Z-WIDTH = 0.

RADII, FOLLOWED BY Z-COORD. OF HOR. PLANES
20.000 8.000 0.
-27.000 -27.000

RING(ARG)= 1
-27.000 -12.000

RING(ARG)= 2
-27.000 12.000

RING(ARG)= 3
22.000 22.000

SUBREGION	GEOM.	PART	REMARKS	MATRNB.	VOLUME	SURFACE	SECTOR	SECTORBOUNDARIES(RADIANS)
0	SLAB	1		6	1440.000	0.		
0	SPACE	0	ATTENTION	5				
1	SHELL	1		4	3015.929	0.		
2	SHELL	1	STARTREG.	1	4825.486	0.		
3	SHELL	2		3	2873.544	-0.	2	2.96706-3.31613
3	SHELL	2		2	36811.613	1697.410	1	3.31613-2.96706
3	SHELL	1		4	2010.619	0.		

APPENDIX 2

Algorithmics and schematic flow charts for calculating the distance S along the line of flight to the boundary of the zone

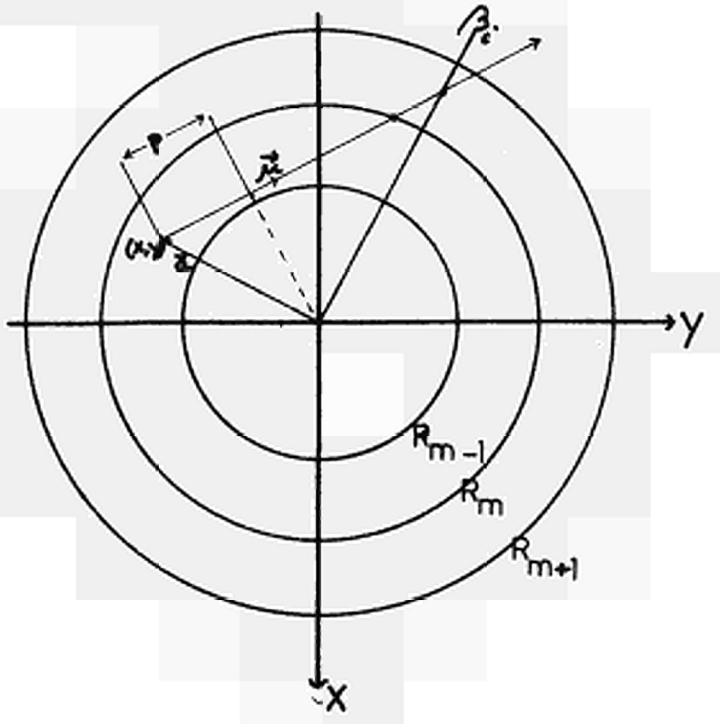
Assume:

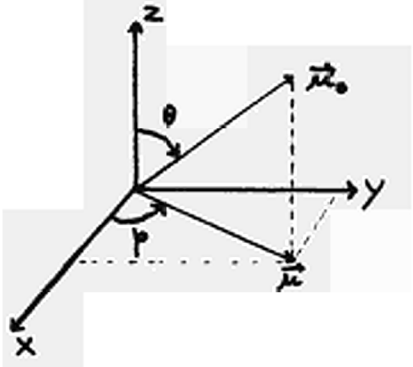
X)
Y) rectangular coordinates of the starting position of the neutron.
Z)

$\bar{X}$)
$\bar{Y}$) " " " " crossing point with the boundary.
$\bar{Z}$)

sin φ)
cos φ) direction of the flight path.
sin Θ)
cos Θ)

1) The distance s along the projection of the flight path on the x-y-plane to a circle and to a radius.





s is projection of S on the x-y-plane

$\vec{\tau}$ is direction sector wall. $\vec{\tau} = (-\sin\beta , \cos\beta)$

$\vec{a} = (X,Y)$

$\vec{\mu} = (\cos\varphi , \sin\varphi)$

Distance to a circle

(1) $\bar{X}^2 + \bar{Y}^2 = R^2$

(2) $\vec{a} + s\vec{\mu} = (\bar{X},\bar{Y})$

(3) $s > 0$

From (1) and (2): $(X + s.\cos\varphi)^2 + (Y + s.\sin\varphi)^2 = R^2$

which gives: $s^2 + 2s.(X.\cos\varphi + Y.\sin\varphi) - (R^2 - X^2 - Y^2) = 0$

If $P = -(X.\cos\varphi) + Y.\sin\varphi)$ and $Q = X^2 + Y^2 - P^2$,

then

$$s_{1,2} = P \pm \sqrt{R^2 - Q} \qquad , R^2 \geq Q$$

Distance to a sector boundary

(1) $\vec{a} + s.\vec{\mu} = \tau.\vec{\tau}$

which is equal to

$X + s.\cos\varphi = -\tau.\sin\beta$

$Y + s.\sin\varphi = \tau.\cos\beta$

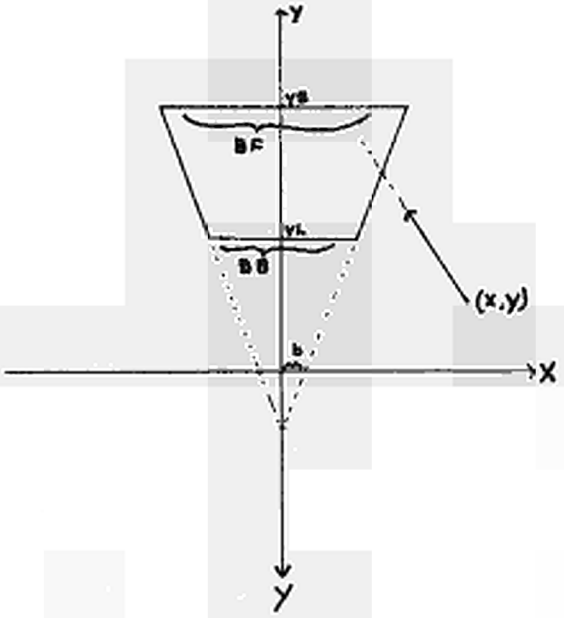
This has the solution:

$$s = \frac{-X\cos\beta - Y\sin\beta}{\cos\varphi.\cos\beta + \sin\varphi.\sin\beta}$$

$$\tau = \frac{Y + s.\sin\varphi}{\cos\beta}$$

They are only valid if $s \geq 0$, $\tau \geq 0$

(2) The distance s along the projection of the flight path on the x-y plane to a line not parallel to an axis (bridge situation).



Equation for a line:

$$x = ay + b \qquad (1)$$

for the neutron path:

$$x = my + n \qquad (2)$$

From (1) and (2) is found:

$$\bar{Y} = \frac{n - b}{a - m}$$

$$s = \frac{\bar{Y} - Y}{\sin\varphi} = \frac{n-b - Y(a-m)}{(a-m)\sin\varphi} =$$

$$\frac{b+aY - n-mY}{m\sin\varphi - a\sin\varphi} = \frac{b+aY - X}{\cos\varphi - a\sin\varphi}$$

For the bridge in the 1st quadrant

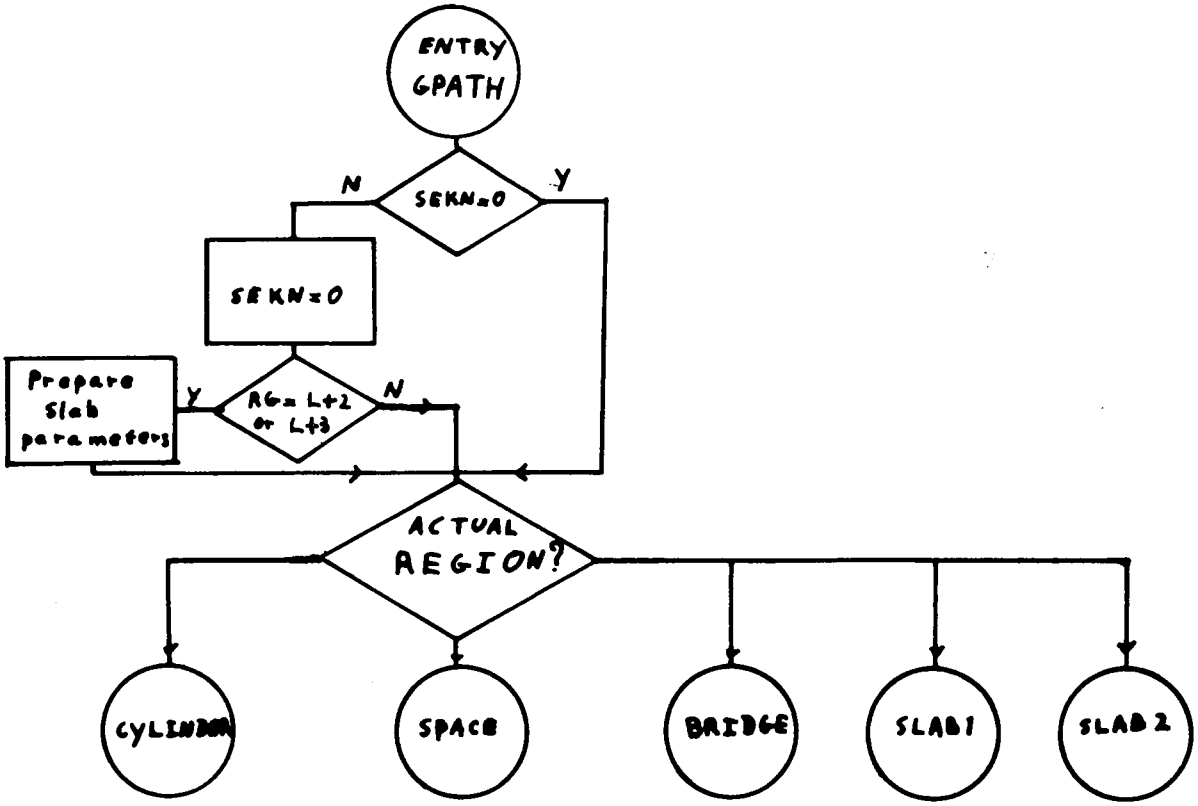
$$a_1 = \frac{BF - BB}{2\cdot(YB - YL)}$$

$$b_1 = 1/2\ BB - a_1 \cdot YL$$

in the 2nd quadrant

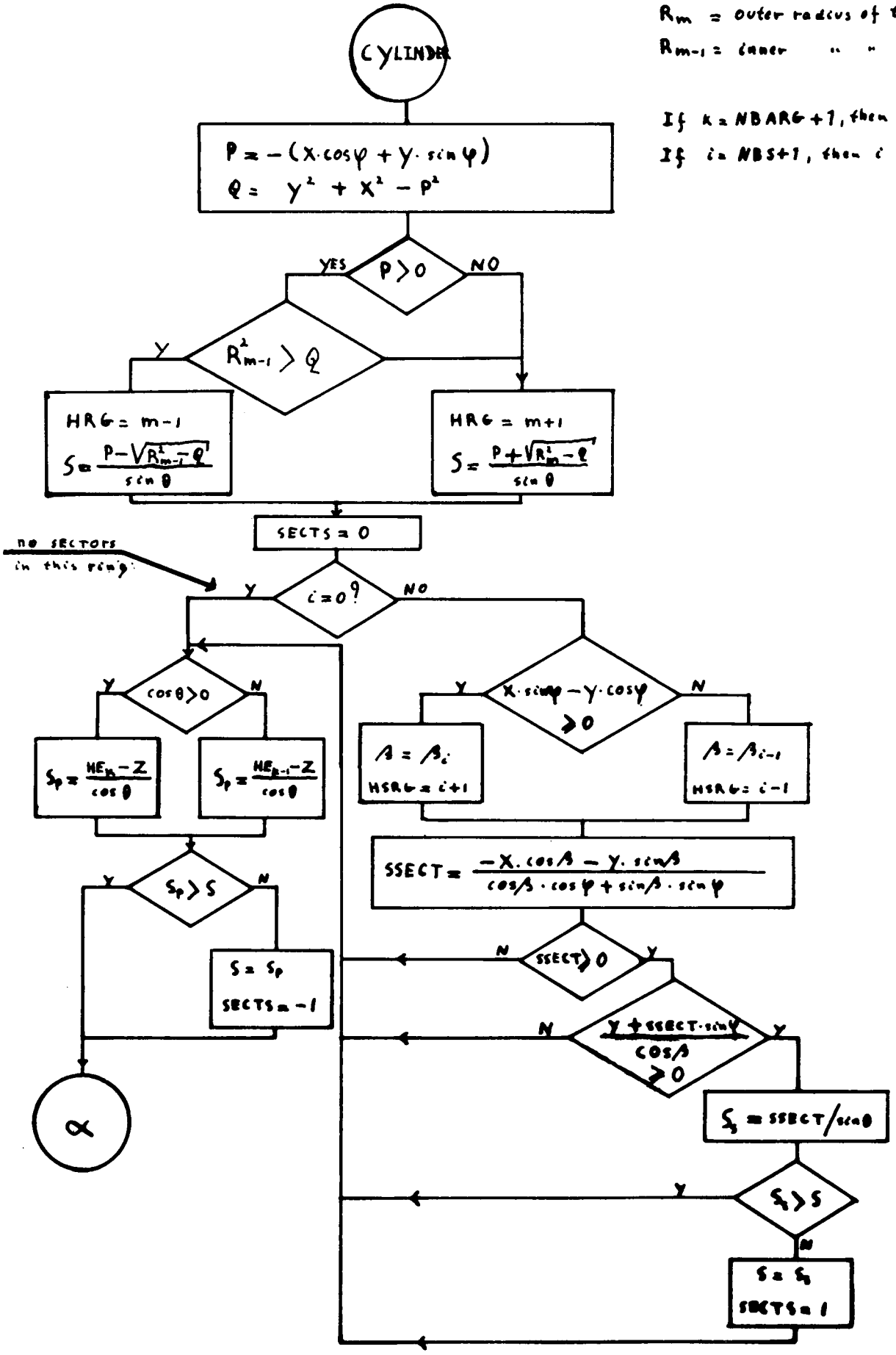
$$a_2 = -a_1$$

$$b_2 = -b_1$$



SOME NOTATIONS:

m = RG
K = ARG
i = SRG (i = 0 : no sectors in the ring).
S = length of flight path to possible next crossing point.
HRG, HARG, HSRG } next region, subregion and sectorregion if crossing occurs.
SECTS = 0 if crossing the cylindrical boundary.
" = 1 " " " sector boundary.
" = -1 " " " horizontal plane in the cylindrical system.
" = -2 " " " bridge or the window.



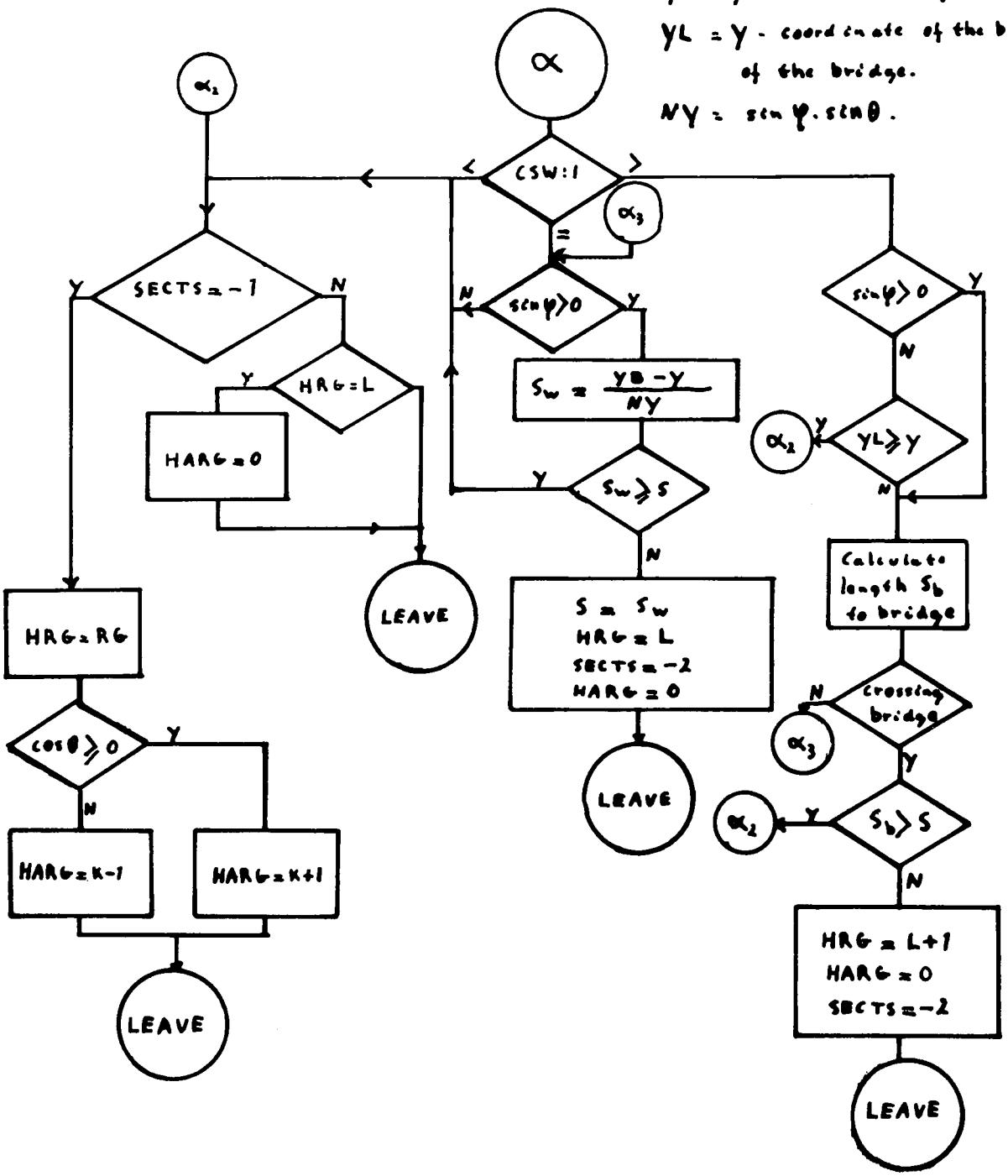
R_m = outer radius of the cyl.shell m.

R_{m-1} = inner " " " " " "

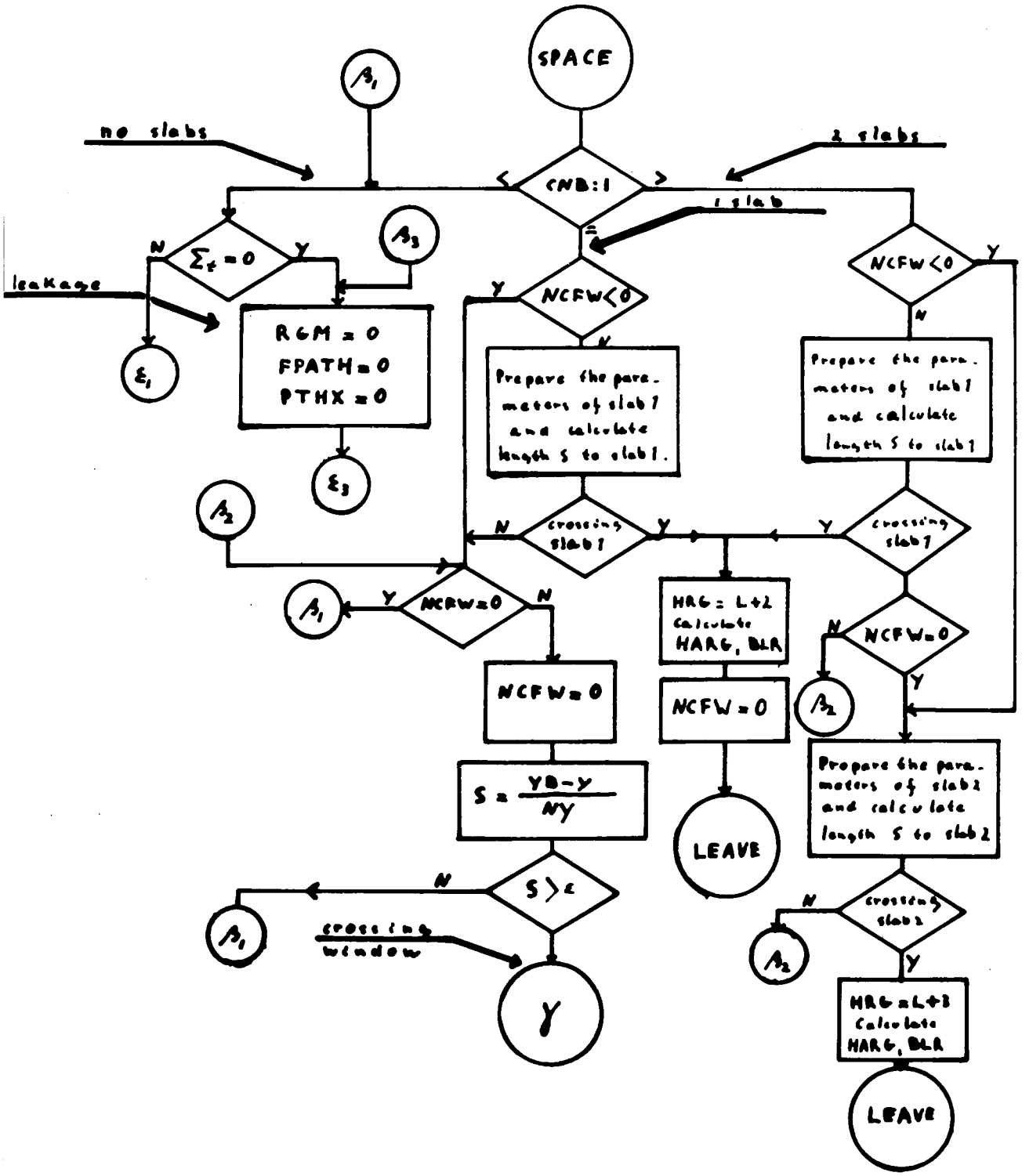
If K = NBARG+1, then K is set = 0.

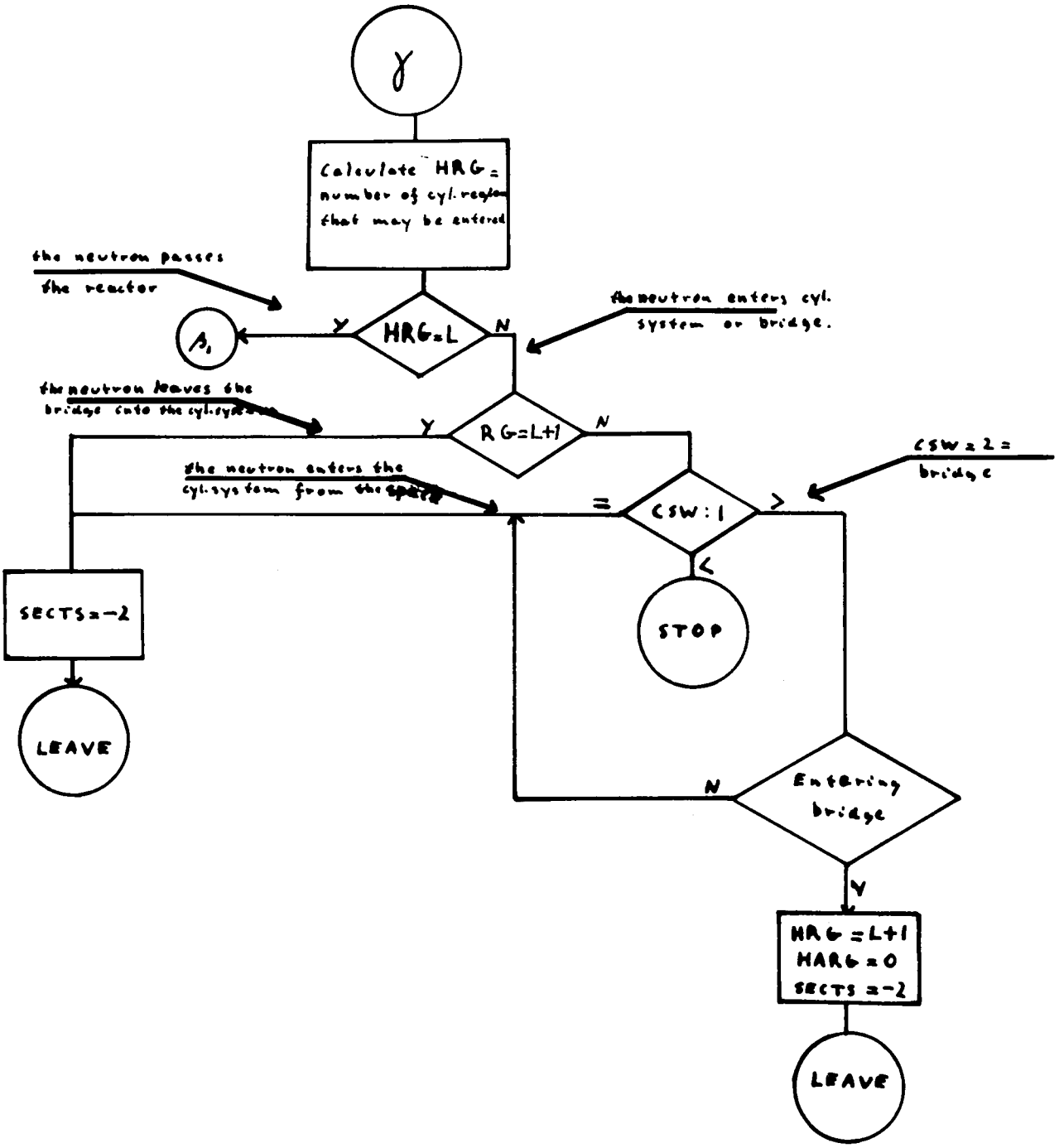
If i = NBS+1, then i is set = 1.

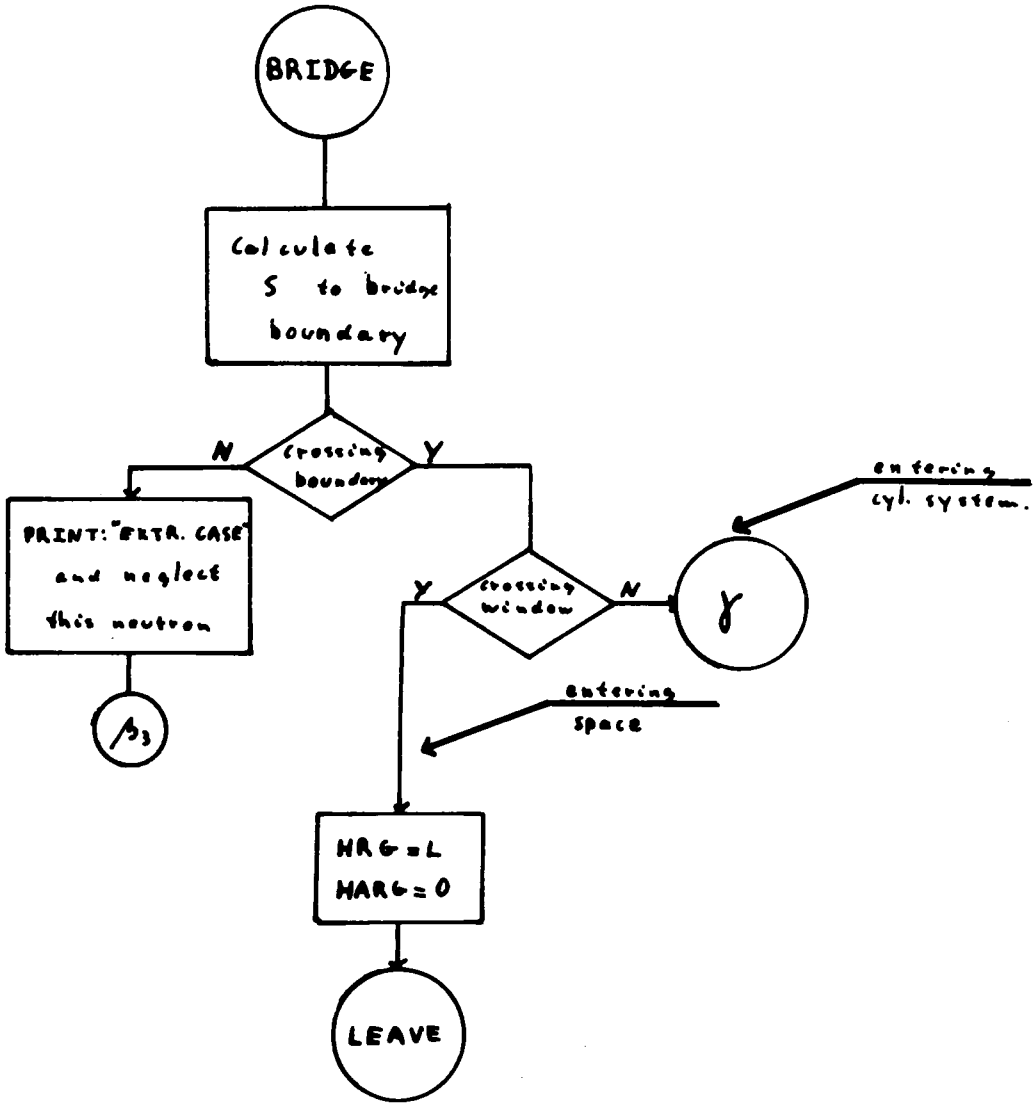
CSW : 0 = no window,
1 = window.
2 = window + bridge.
L = the space region (surrounding
YB = Y - coordinate of the windo
YL = Y - coordinate of the backpla
of the bridge.
NY = sin φ . sin θ .

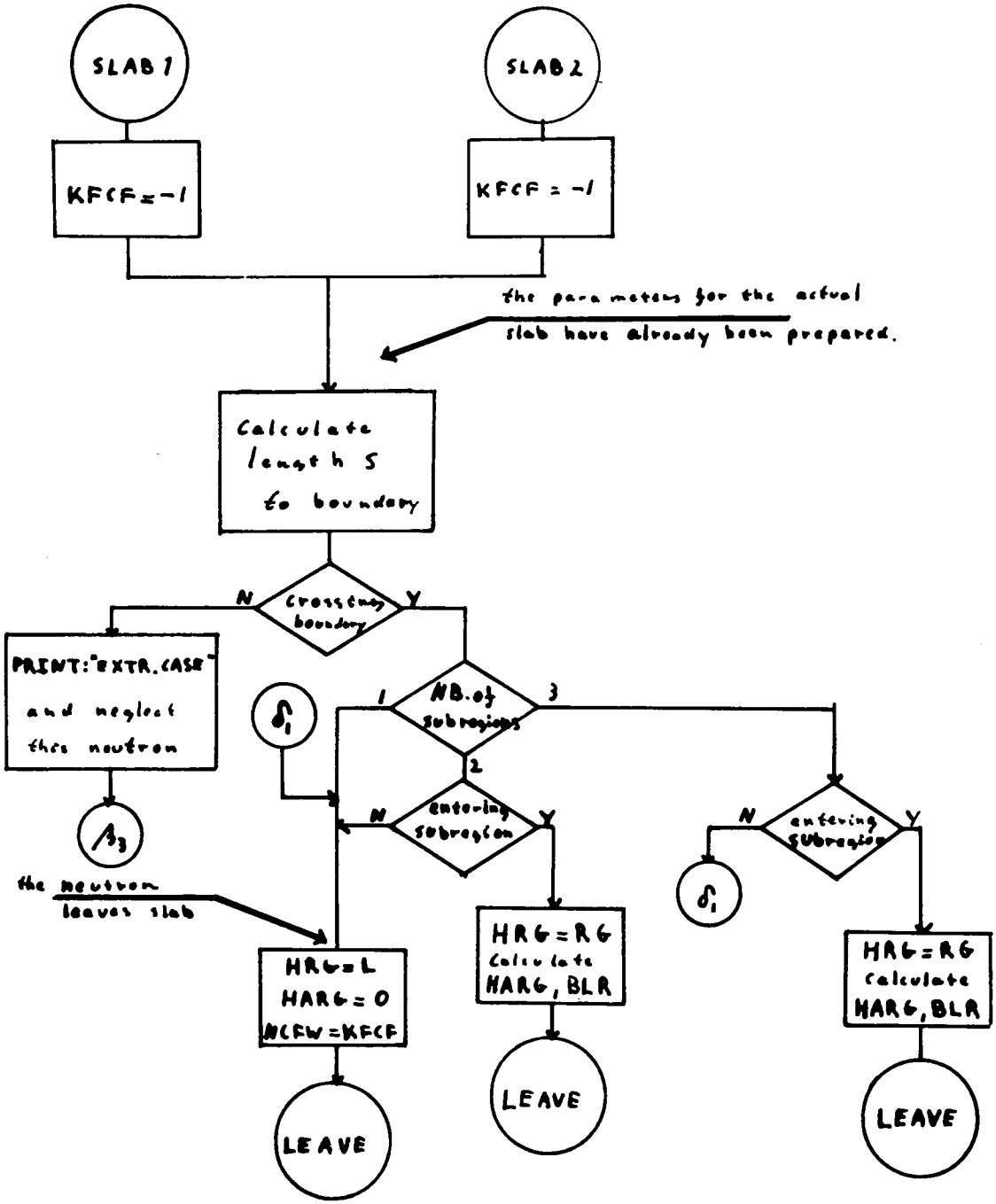


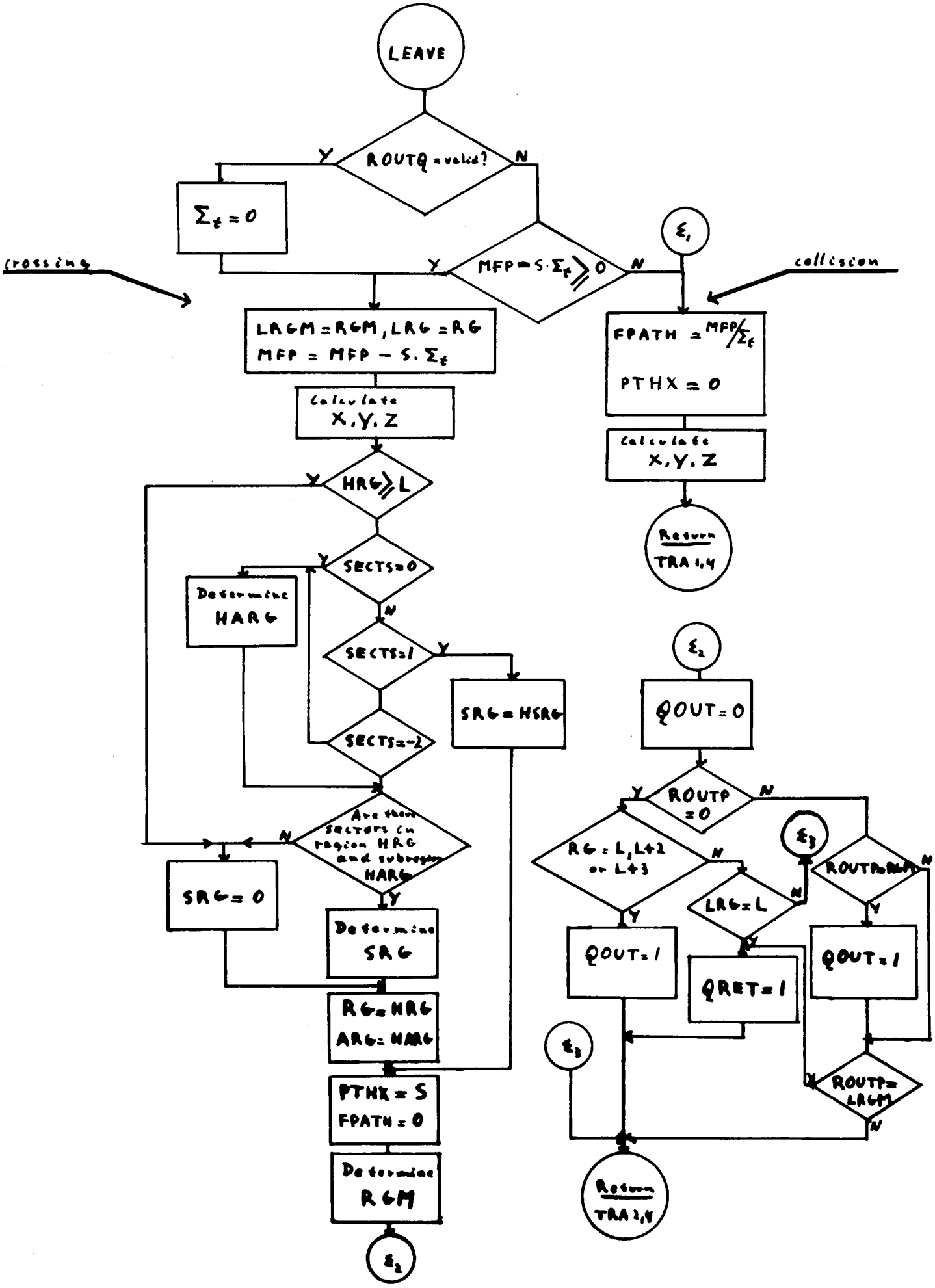
NCFW = -1 if last region was slab 1.
NCFW = 1 " " " " slab 2.
Otherwise NCFW = 0.
$\varepsilon = 0.00001$
CNB = Number of slabs.




γ
Calculate HRG = number of cyl. region that may be entered
the neutron passes the reactor
HRG=L
Y
N
A1
the neutron enters cyl. system or bridge.
the neutron leaves the bridge onto the cyl.system
RG=L+1
Y
N
CSW = 2 = bridge
the neutron enters the cyl.system from the
CSW : 1
=
>
<
SECTS=-2
STOP
LEAVE
N
Entering bridge
Y
HRG = L+1
HARG = 0
SECTS = -2
LEAVE


BRIDGE
Calculate S to bridge boundary
crossing boundary
N
Y
PRINT: "ERR. CASE" and neglect this neutron
entering cyl. system.
crossing window
Y
N
entering space
HRG = L
HARG = 0
LEAVE


SLAB 1
SLAB 2
KFCF=-1
KFCF = -1
the parameters for the actual slab have already been prepared.
Calculate length S to boundary
N
Crossing boundary
Y
PRINT: "EXTR. CASE" and neglect this neutron
δ_3
the neutron leaves slab
δ_1
1
NB. of subregions
3
2
N
entering subregion
Y
HRG=L
HARG=0
NCFW=KFCF
HRG=RG
Calculate HARG, BLR
N
entering subregion
Y
δ_1
HRG=RG
Calculate HARG, BLR
LEAVE
LEAVE
LEAVE


LEAVE
ROUTQ = valid?
Y
N
$\Sigma_t = 0$
$\mathcal{E}_1$
crossing
MFP = S·Σ_t ⩾ 0
Y
N
collision
LRGM = RGM, LRG = RG
MFP = MFP − S·Σ_t
FPATH = MFP/Σ_t
PTHX = 0
Calculate X, Y, Z
Calculate X, Y, Z
HRG ⩾ L
Return TRA 1,4
SECTS = 0
Determine HARG
SECTS = 1
SECTS = -2
SRG = HSRG
$\mathcal{E}_2$
QOUT = 0
Are there sectors in region HRG and subregion HARG
ROUTP = 0
RG = L, L+2 or L+3
$\mathcal{E}_3$
ROUTP = RGM
LRG = L
SRG = 0
Determine SRG
QOUT = 1
QRET = 1
QOUT = 1
$\mathcal{E}_3$
ROUTP = LRGM
RG = HRG
ARG = HARG
PTHX = S
FPATH = 0
Determine RGM
$\mathcal{E}_2$
Return TRA 2,4

APPENDIX 3

Starting points

Let τ_i be generated random numbers between 0 and 1.

1) Selection of geometrical starting region:

V_i = volume of starting region number i in the list of starting regions.
The starting region J is selected by:

$$\frac{\sum_{i=1}^{J-1} V_i}{\sum_{i=1}^{I} V_i} < \tau \leqslant \frac{\sum_{i=1}^{J} V_i}{\sum_{i=1}^{I} V_i}$$

I = total number of start regions.

The selected region may be a ring, a sector in a ring, the bridge or a slab.

2) Selection of starting point in a ring or in a sector.
Suppose in shell m, ring k (= subregion k) and eventually sector i.

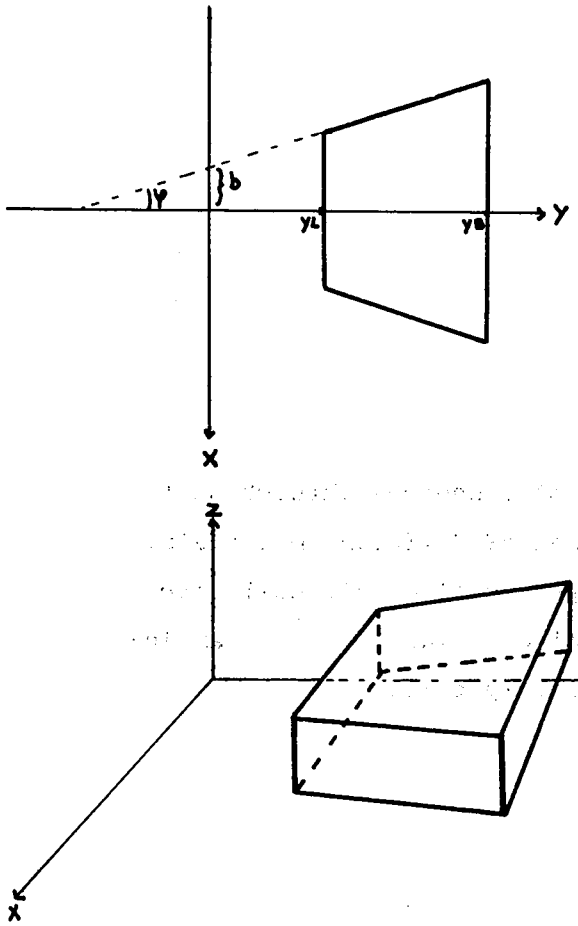
$$R = \sqrt{R_{m-1}^2 + \tau_1 \, (R_m^2 - R_{m-1}^2)}$$

$$Z = \tau_2 \, (HE_{m,k} - HE_{m,k-1}) + HE_{m,k-1}$$

If i = 0 (no sector) a random $\cos\alpha$ and corresponding $\sin\alpha$ are generated.
If $i \neq 0$: $\alpha = \beta_{i-1,m,k} + \tau \left(\beta_{i,m,k} - \beta_{i-1,m,k} \right)$ and $\cos\alpha$ and $\sin\alpha$ are calculated from α .

$$X = R \cdot \cos\alpha \, . \qquad Y = R \cdot \sin\alpha \, .$$

3) Selection of starting point in bridge or slab.



Bridge:

$Y = YL + \tau_1 \cdot (YB - YL)$

$Z = WH \cdot (\tau_2 - \frac{1}{2})$

$X = (Y \cdot \tan\varphi + b) \cdot (2\,\tau_3 - 1)$

Slab:

$X = X_{center} + (\tau - \frac{1}{2}) \cdot W_x$

W_x = width of slab in x direction.

Etc.

GSPHER - A Geometry routine for concentric spheres in parallelepipeds

H. Kschwendt

1. Summary

This routine permits to calculate the trace of a neutron through up to 20 concentric spheres, which might be composed of different materials. These spheres are imbedded in a parallelepiped, called unit cell. The whole configuration may either be composed of one single cell or an infinite, periodic lattice array of such elementary cells.

2. General

Given the position of a neutron in a certain geometrical region, the direction of flight, and the number of mean free paths λ, the programme GSPHER calculates the crossing point of the neutron trajectory with the boundary of the present region. If the given λ is larger than the distance (in mean free paths) to the boundary, the next event is defined as boundary crossing. The programme GSPHER then calculates the position of the boundary crossing, reduces λ by the corresponding amount and returns to the RWS programme of the TIMOC code [1] via the exit 2,4. If the given λ is smaller than the distance to the boundary, the next event is a collision. GSPHER then calculates the position of that collision and returns via the exit 1,4 to the RWS programme of the TIMOC code.

3. Communications with the RWS programme

In the sequel, we list all storage locations, together with a description, which are used for the communication between the GSPHER and the RWS programme. These parameters are stored in COMMON in the order described here. In the list, we use f for a floating point number and i for an integer.

RG — (i). Index of the geometrical region where the neutron actually is. After a boundary crossing, RG contains the index of the new geometrical region. The index is stored in the decrement part of RG.

RGH, RGL — Not used in the GSPHER programme.

X, Y, Z — (f). Coordinates of the position of a neutron, in cartesian coordinates.

SINP, COSP, SINT, COST (f). $\sin\varphi$, $\cos\varphi$, $\sin\vartheta$ and $\cos\vartheta$, where φ and ϑ are the spherical coordinates of the flight vector of the neutron.

SGT (f). Total macroscopic cross section of the geometrical region RG.

MFP (f). Number of mean free paths λ , which a neutron has to travel before making another collision.

PTHD (f). Distance between the last and the actual event in cm, if the actual event is a collision.

PTHX (f). Distance between the last and the actual event in cm, if the actual event is a boundary crossing.

NRG (i). Starting region. Must be specified in the NDP programme of the TIMOC code.

QRET (i). Is used, if in the corresponding RWS programme the SMEC*option is specified. If the neutron leaves the perturbed region, QRET = 1 (address part).

QOUT (i). Is used, if in the corresponding RWS programme the SMEC*option is specified. If the neutron enters the perturbed region, the tag bits 1, 2 and 4 of QOUT are filled with 1.

QSEKN, BLR Not used in the GSPHER programme

QSTPT (i). If ≠ 0: fixed starting point of primary neutrons.

QTIME (i). If ≠ 0: the geometry input data are also placed on the time tape B6.

QCOLL (i). The GSPHER programme sets QCOLL ≠ 0 in the case of a collision and QCOLL = 0 in the case of a boundary crossing.

QBLOC (i). If ≠ 0: it is possible to obtain the leakage from a single unit cell. The region around the unit cell gets assigned a region number which is by definition LMAX+1, and has to be defined as leakage re-

gion in the NDP programme of the TIMOC code. This results in the neutrons not being reflected from the walls of the unit cell - as it is done in the infinite lattice array - but leaking out of the assembly.

SRG } Not used in the GSPHER programme
COEND}

4. Entries

GREAD This subroutine reads and test the input data.

GPRNT This subroutine prints the input data.

GSTRT If QSTRT = 0, a random starting point (coordinates X, Y and Z) is determined in the region specified by NRG in the NDP programme of the TIMOC code. For the calculation of the random numbers, the subroutines of the RWS programme are used. If QSTRT $\neq$ 0, the control returns directly to the RWS programme.

GPATH This is the most important subroutine of the GSPHER programme. It calculates the type and position of the next event.

In the case of a boundary crossing (return 2,4), the following parameters are replaced by their new values: RG, X, Y, Z, MFP, PTHD = 0, PTHX, eventually QRET or QOUT, QCOLL = 0. In the case of a collision (return 1,4), the following parameters are replaced by their new values: X, Y, Z, PTHD, PTHX = 0, QCOLL $\neq$ 0.

CELL This subroutine calculates the volume of the different regions. The routine expects in the AC-register the region index (in the address part). When returning to the RWS programme, the AC-register contains the volume of the region under consideration and the MQ-register contains the outer radius of the corresponding sphere.

SURFC This subroutine calculates the area of the different surfaces. The routine expects in the AC-register the region index (in the address part). When returning to the RWS programme, the AC-register contains the area of the surface and the MQ-register contains the corresponding radius. The correspondence is made in such a way that for

the index 1, one obtains the area and the radius of the biggest sphere.

PROJ This subroutine calculates after each boundary crossing the projection of the direction of flight of the neutron on the surface normal. In the case of an outgoing neutron (in the direction of increasing distance from the origin) the projection will be positive, otherwise negative. When returning to the RWS programme, the projection is placed in the AC-register. The MQ-register contains, in the decrement part, a region index. If the projection is positive, this index corresponds to the previous region, if the projection is negative, this index is that of the actual (new) region.

END Dummy entry. Defines the last location of the GSPHER programme.

BVTBF Dummy entry. Defines the end of the programme part of GSPHER, which is kept in the computer, while the storage locations between BVTBF and END are cleared after the input is made and checked in order to savestorage locations.

GEPR, GERJ } In these subroutines, several auxiliary constants are calculated after the input is read and checked.

NAME Dummy entry. Contains the name of the geometry programme, GSPHER.

GMAC, GEDS, GINP } Dummy entries. Not used in the GSPHER programme.

5. Input

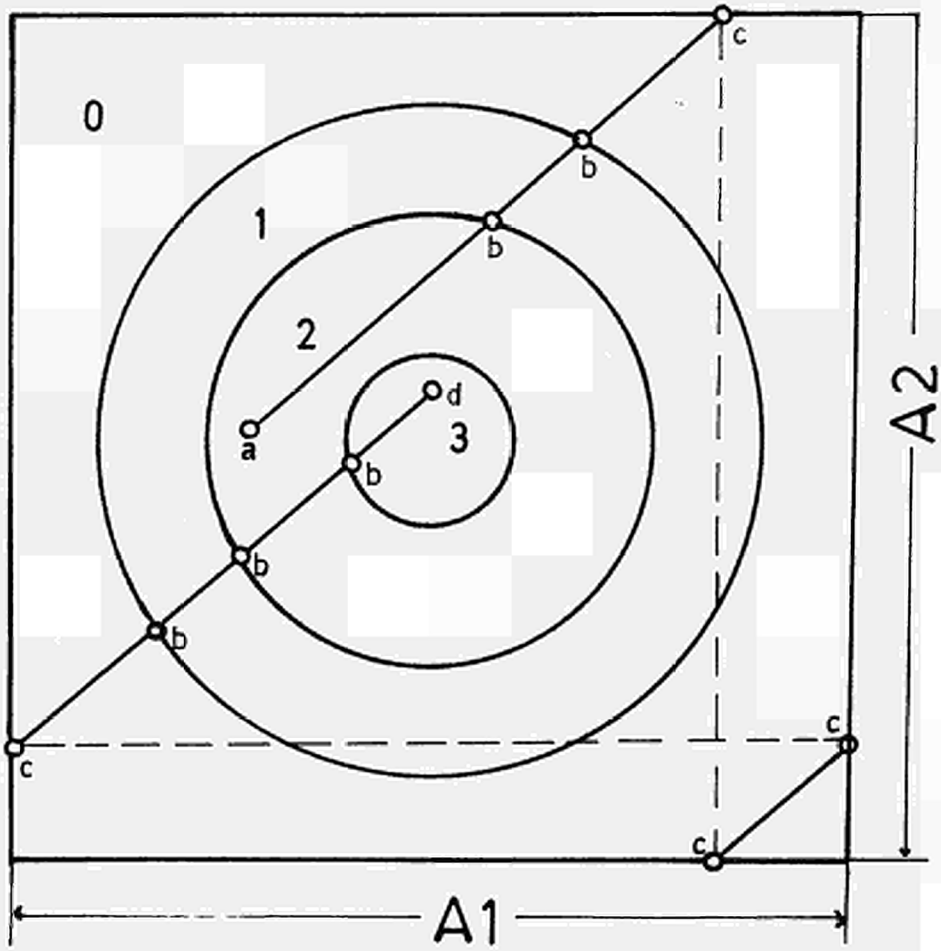
The input is made as in the RWS programme using the WPKO6 routine. The input format is described in connection with the SORSEC geometry programme on page 16.

We consider the geometrical configuration as described in Fig. 1 (3-dimensional!). For simplicity we have assumed three concentric spheres

placed in the unit cell. The regions are defined as shown in Fig. 1, that is, the region outside the biggest sphere is region 0 by definition and the shells are named in consecutive, increasing order. These regions must correspond to the material regions as defined in the NDP programme of the TIMOC code. If in the NDP programme the region 0 is defined as leakage region, one single unit cell is considered, since the history of the neutron is terminated when leaving the biggest sphere. If in the RWS programme the LEAK*option is not used, the unit cell is assumed to be a part of an infinite, periodic lattice array of such cells. In this case, the coordinates of the neutron are reduced by the lattice constants when the neutron is leaving the unit cell, as indicated in Fig. 1.

In the following description of the input parameters, f stands for a floating point number and i for an integer. Examples are given in sec. 12 of the description of the TIMOC code [1].

Columns	Contents	Description
8-10	DEC	
12 cont.	i	N: Must be 20 (for indentification purposes).
	i	SE: If in the corresponding RWS programme the SMEC*option is specified, the perturbed region has to be defined here. Otherwise SE = 0.
	i	LMAX: Number of concentric spheres, $1 \leq LMAX \leq 20$. In Fig. 1, LMAX = 3.
	i	Must contain 0.
	f	R(1): Radius of the inner sphere.
	⋮	⋮ All radii must be positive
	⋮	⋮ and placed in increasing
	f	R(LMAX) order.
	f	A1, A2, A3: Lattice constants in the X-, X- and Z-direction. Must be larger than twice R(LMAX).
8-10	TRA	
12-14	4,4	



a: Starting point,

b: Boundary crossing,

c: Crossing with the wall of the unit cell and reduction of the coordinate,

d: Collision point.

Fig. 1. Sketch of the GSPHER geometry with region identification and typical neutron path.

SLBCYL - A Geometry Routine for Infinite Slabs or Infinite Concentric Cylinders in a Rectangular Lattice

R.J. Jaarsma

Summary

This routine was originally written for the REP-Monte Carlo code[1]. It was adopted to TIMOC and permits the calculation of the following configurations:

a. A number of infinite parallel slabs.

b. A system of infinite concentric cylinders placed in a regular staggered or unstaggered rectangular lattice or in a hexagonal lattice.

1) R.D. Richtmyer, R. van Norton, and A. Wolfe, "The Monte Carlo calculation of resonance capture in reactor lattices", 15/P/2489, Proc. 2nd UN Int. Conf. on Peaceful Uses of Atomic Energy, UN, Geneva, 1958.

1) Geometry

The geometrical regions are directly indentified with the regions defined in the input of the Nuclear Data Preparation Program, named LCH (see TIMOC report (1), section 9.1, page 92, card 8).

The system of indexing the geometrical regions is made clear by the diagrams in chapter 5, illustrating the input data preparation.

2) Calculation

The method of calculation is the same as in SORSEC (p.10), with the restriction that the calculation is one or two dimensional. Therefore the subroutine GPATH starts with the calculation of the projection of λ on the X-Y plane (lattice system) or on the X-axis (slabs system). At the end of the calculation the distance to crossing or collision point is again converted to three-dimensional space.

3) Communication with the RWS program

A set of parameters, whose values at any time suffice to completely characterize the neutron, is stored in the COMMON part, with the following notation (I = integer, F = floating point number):

RG: Actual geometrical region = actual region index as used in the program RWS (1). (It has to be stored in the decrement part of the location). (I)

DUM1: No meaning (2 locations)

X: } Rectangular plane coordinates, giving the position of the
Y: } neutron. (F)

DUM2: No meaning

SINP:
COSP:
SINT:
COST:

Defining φ and ϑ, being the spherical coordinates for the direction vector.(F)

SGT: Total cross section of material RG. (F)

MFPC: Number of mean free paths (λ) in the flight path of the neutron. (F)

PTHD: Length of the flight path to the next collision point in cm. (F)

PTHX: Length of flight path to a crossing point in cm.

NRG: No meaning.

DUM3: No meaning (4 locations).

QSTPT: If $\neq$ 0: fixed starting point of primary neutrons.

QTIME: If $\neq$ 0: the geometry input data are also written once on the tape of unit B6.

QCOLL: This parameter is controlled as follows: When the RWS program starts a new neutron, it sets QCOLL $\neq$ 0. The GEOMETRY program sets QCOLL = 0 in the case of a crossing and sets QCOLL $\neq$ 0 in the case of a collision.

DUM4: No meaning. (2 locations).

4) Entries

GREAD This part reads the input data and tests it.

GPRNT This part prints the input data.

GSTRT In the case QSTPT = 0 a random starting point in region RG is calculated by this part and the parameters X and Y are set. If QSTPT $\neq$ 0 the control returns direct to the calling program and GSTRT has no effect.

GPATH This part calculates a crossing or collision point of the neutron.

In the case of a crossing into another region, the return transfer into the main program is to the second location after the calling instruction. The following parameters are always replaced by their new values: RG, X, Y (not in the slab geometry) and MFPC. QCOLL is made equal zero, so is PTHD. PTHX is the flight path which the neutron travels to the crossing point.

In the case of a collision, the return transfer into the main program is to the first location after the calling instruction. The following parameters are always replaced by their new values: X and Y (not in the slab geometry). QCOLL becomes unequal zero, PTHX is set equal zero and PTHD is the flight path which the neutron travels to the collision point.

CELL This part gives the main program a normalization factor. It has to be entered with a region index in the accumulator (address part). When controll returns to the main program the accumulator contains the distance between the slab walls of the corresponding region in the case of slab geometry and the area in the X-Y plane of the corresponding region in the case of cylinder geometry. In both cases the MQ-register contains the floating point representation of the region index.

SURFC This part gives the main program also a normalization factor. The region index is again the argument and in the case of slab geometry the accumulator contains the number 1.0 and the MQ-register the X-coordinate of the corresponding region; in the case of cylinder geometry the circumference and the radius respectively.

PROJ This part gives information about the projection of the direction vector either on the X-axes (if slab geometry) or on the radius through the point of crossing (for cylinders). The return is to the third location after the calling instruction. The accumulator contains the projection and the MQ register contains a region index. In the slab geometry this index is of the region just left by the neutron if it moves in the positive X-direction (the pro-

jection is positive) and of the region that will be entered, if the neutron moves in the negative X-direction (the projection is negative). In the cylindrical geometry this index is of the region just léft by the neutron if it moves away from the center (the projection is positive) and of the region, that will be entered if it moves toward the center (the projection is negative).

END — This is a dummy entry for knowing the last program location.

NAME — Also a dummy entry where the name SLBCYL has been stored.

GERJ — In the case of QSTPT $\neq$ 0 (fixed starting point) this part calculates the parameter RG from X and Y (the coordinates of the starting point). The values of X and Y have to be produced by the main program before calling this routine. The return is to the 2nd location after the calling instruction if the region has been found. The return is to the 1st location if QSTPT = 0. When the fixed startpoint is inconsistent a message is printed and a transfer to exit is executed.

GEDS — This part may be entered after a collision. If entered the accumulator should have the absorbed weight at the point of the collision. Each region (except region 0) has been divided in 10 intervals with equal volume. The absorbed weight is added, depending of the position of the collision, in one of the intervals. The return is to the first location after the calling instruction.

GMAC — In continuation of GEDS this part may produce at the end of the job the output print of the spatial distribution of absorption per neutron. When this part is entered the accumulator should contain the number of histories. The return is to the first location after the calling instruction.

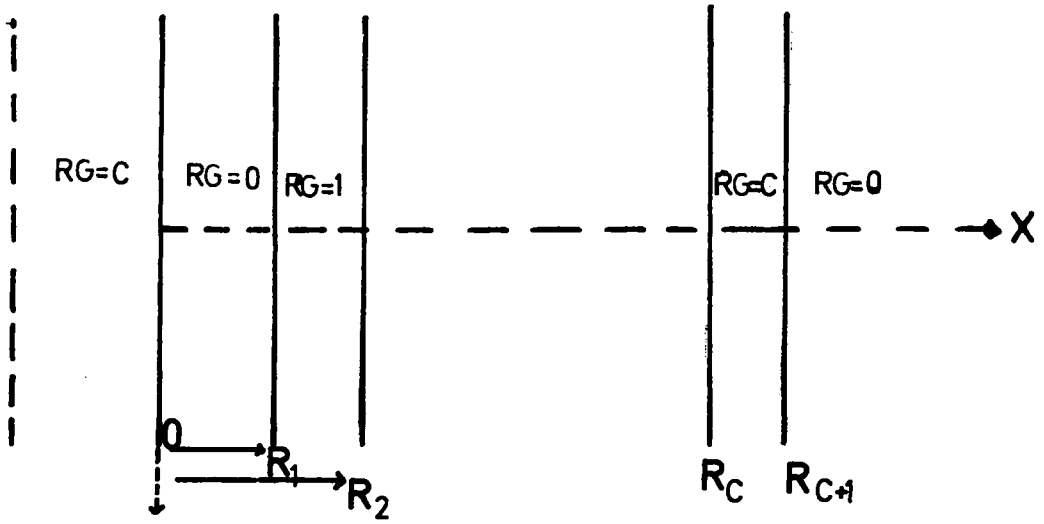
GINP, GEPR, BVTBF are dummy entries without meaning.

The same subroutines as in SORSEC (p. 16) must be added.

5) Input SLBCYL

The data are read by WPKO6 and the FORMAT has been described by SORSEC (p. 16).

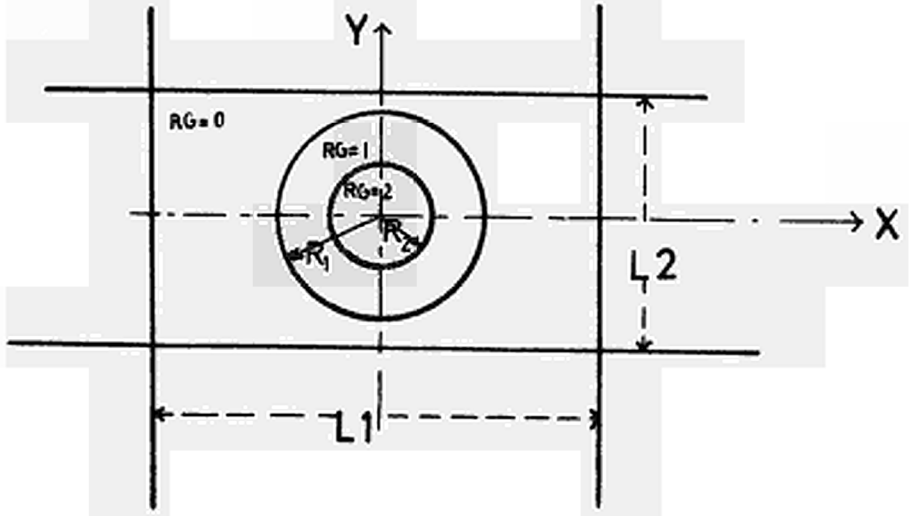
Slabs (Type 111)



The input is checked to assure $R_n < R_{n+1}$ and $1 \leqslant C \leqslant 14$. The input takes the following form.

Value or Symbol	Floating (F) or integer (I)	Explanation
11	I	A sentinel
1	I	" "
C	I	See diagram
O	I	" "
R_1	F	See diagram (in cm)
R_2	F	" " " "
.	.	
.	.	
.	.	
R_{c+1}	F	" " " "

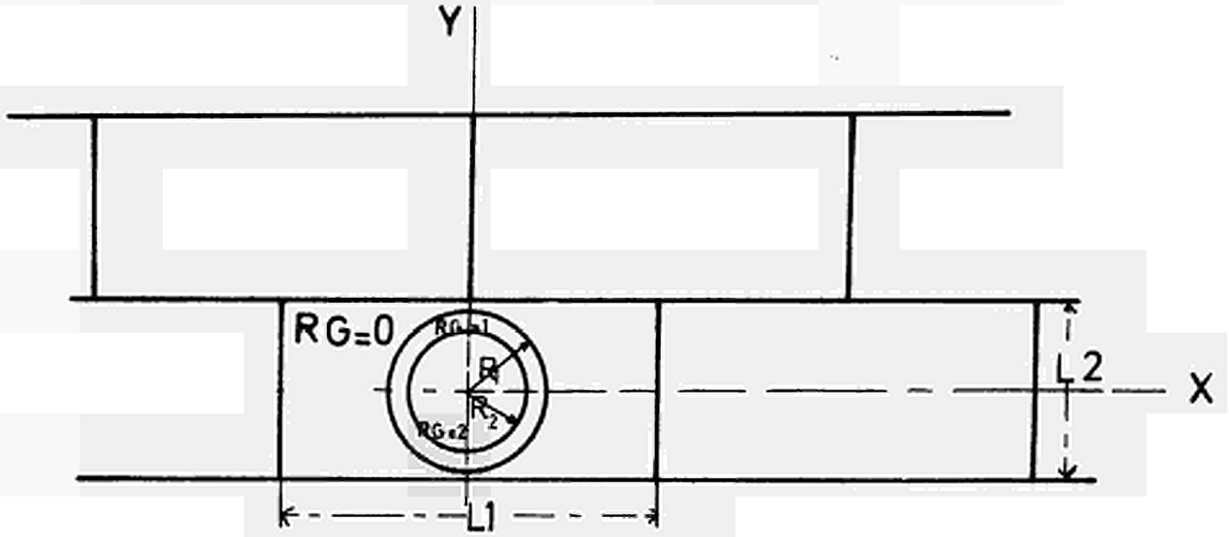
Unstaggered Rectangular Lattice (Type 410)

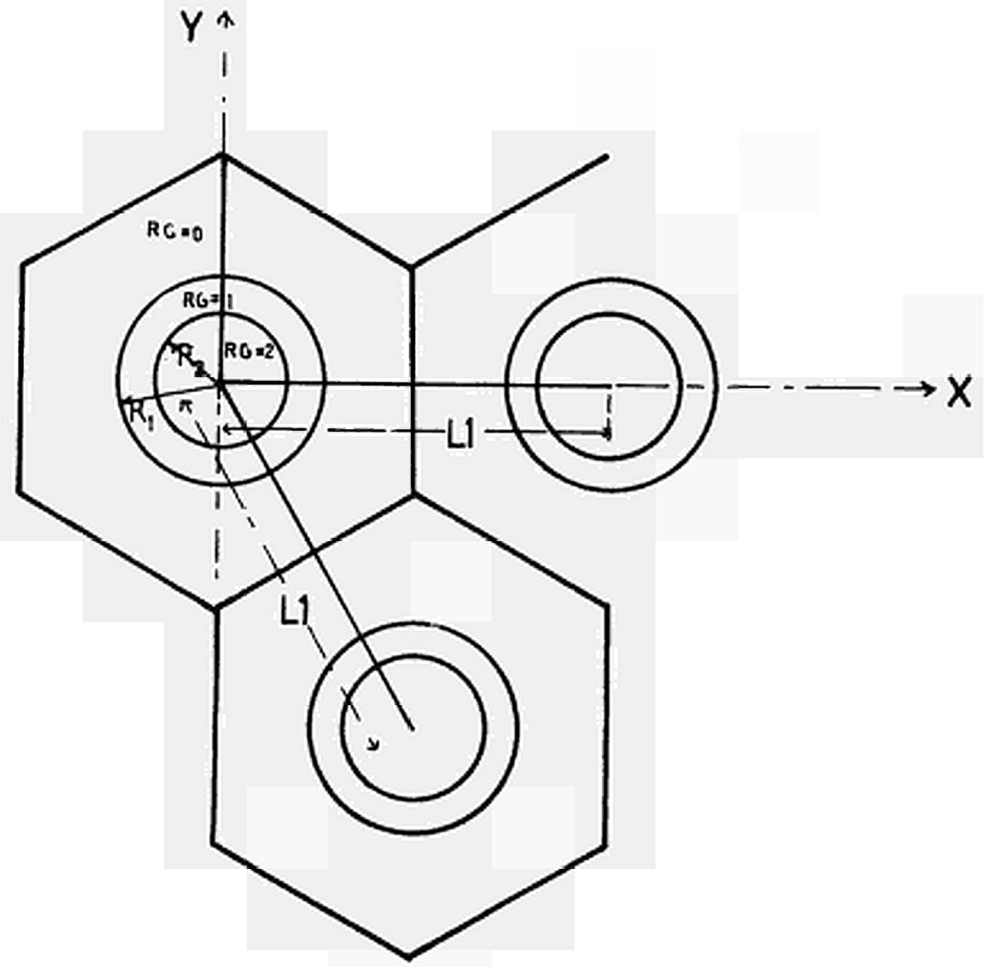


C is the number of regions (concentric cylinders) in the rod. The input is checked to assure $R_n > R_{n+1}$ and $1 \leq C \leq 14$.

Value or symbol	Floating (F) or integer (I)	Explanation
41	I	A sentinel
0	I	" "
C	I	No. of regions in the void
0	I	See diagram
R_c	F	" "
R_{c-1}	F	" "
.	.	
.	.	
.	.	
R_1	F	" "
L_1	F	" "
L_2	F	" "

Staggered Rectangular Lattice and Hexagonal Lattice (Type 411)





C is the number of regions (concentric cylinders) in the rod. The input is checked to assure $R_n > R_{n+1}$ and $1 \leqslant C \leqslant 14$.

Value or symbol	Floating (F) or integer (I)	Explanation
41	I	A sentinel
1	I	" "
C	I	No. of regions in the rod
O	I	See diagram
R_c	F	" "
R_{c-1}	F	" "
.	.	
.	.	
.	.	
R_1	F	" "
L_1	F	" "
L_2	F	" "

For hexagonal lattice, set $L_2 = O$ and L_2 will be set equal to $\frac{\sqrt{3}}{2} \cdot L_1$ by the routine GREAD.

NB. R_1 should be smaller than $\frac{\sqrt{3}}{2} \cdot L_1$.

The O5R-GEOM routine adapted for the use in the TIMOC code

R.J. Jaarsma

1. Summary

Besides the special purpose geometry routines described above also the very general geometry subroutine of the O5R code was adapted to be used in TIMOC. This geometry routine allows the description of bodies and body combinations with surfaces of 2nd order. Owing to the independent structure of the main programme and the geometry subroutine in O5R as well as in TIMOC, this connection can be made with relatively little labour and one way of doing it is described in this article. A start routine making possible the random selection of start points has been added.

2. GENERAL VIEW

2.1 Method

The combination of the TIMOC code with the GEOM set has been made with a minimum of modifications of the existing programmes. However some intermediate subroutines have been introduced. They are invoken by the TIMOC programme and call for the GEOM programme.

The change of the GEOM routines includes only a shift of 128_{10} (= 200_8) locations of the COMMON storage by starting COMMON with a dummy array of dimension 128. A complete map of the COMMON locations is given in section 5.

The modification of the TIMOC programme can be made without making a new assembly. By means of the pseudo FAP-instruction ORG a separate assembly of the modifications can be made, producing binary cards. These cards must then be added to the normal TIMOC binary deck to realize the modifications. One of the changes is the replacing of the first free COMMON location, the other changes are only related to the temporary storing of the packed word RGH (a copy of BLZON, an auxiliary parameter to define the neutron's geometrical position). A storage of 400 words is necessary for secondary neutrons, coming into existence after fission, and a storage of 50 words to remember the status of the crossing points if the Expected Leakage Probability specification has been applied. These two stores overwrite a part of the memory occupied by the input programme, which is no longer used at that moment. In section 6 is shown a list of the replacing instructions.

A complete set of descriptions of the added subroutines is given in section 7.

Calculations have shown that the calculation time with the O5R-GEOM routine can be 50 to 100% larger than with the corresponding special purpose geometry routine.

It should be noticed that all compilations and executions are made under the Fortran 2, Version 2 Monitor of the IBM 7090 computer.

2.2 Restrictions

It is not possible to calculate the volume of any sector nor the area of any surface. The final results of the TIMOC code are therefore not normalized per cm^3 or cm^2. Also the projection of the direction vector on surfaces is not calculated. Therefore the specification TRAN in the input data of the TIMOC code will always be without any meaning and should not be used. Printing of the geometry data is only done by the subroutine JOMIN and not by GPRNT.

2.3 SMEC (Small Effect Calculations

The TIMOC feature SMEC assumes control of the parameters QRET and QOUT by the geometry programme. The maximum number of media to which the SMEC feature may be applied is 8. When a neutron enters such a medium, QOUT is set equal 1 (tag part), otherwise equal 0. When leaving such a medium, QRET is set equal 1 (last bit).

2.4 Start routine

As the GEOM deck did not contain any start routine, this has been added. The start routine makes possible the random selection of a start point in a sector belonging to a randomly selected start block. A start block is a block containing one or more start sectors, which all have the same medium. The maximum number of start blocks is 8. To each start block there must be added a probability weight, which is applied when a start block is selected. The medium number in a start sector must be unique in the accessory block. The coordinates are randomly selected in the start block and rejected if the medium containing these coordinates is not the medium of the start sector. This rejection technique is repeated a maximum of 1000 times, after which a message will be printed and the programme stops.

N.B. From the definition of a start block follows that start sectors with different media in one block must be defined as being in different start blocks.

3. INPUT

The normal GEOM input (2) is followed by the following cards.

```
                a  b  c
Card S: Format (I6,I6,8I6)
```

a. The number of start blocks.

b. The number of media to which the SMEC feature will be applied.

c. These medium numbers themselves.

```
                  a      b      c      d     e
Card T: Format (E12.5, E12.5,E12.5, E12.5,I6)
```

For each start block one card.

a. X-coordinate)

b. Y-coordinate) of any point in a start sector of the start block.

c. Z-coordinate)

d. The weight given to the start block.

e. The number of the medium contained in the start sector(s).

The normal GEOM input is as described in the O5R report with the change that the medium number 1000 no longer refers to internal void. Used in combination with TIMOC, all media are defined by TIMOC where internal void may be defined as a medium with a density of zero. Leakage or external void retains the medium number 0. Also in the case of a fixed starting point (STPT-specification in TIMOC) the cards S and T must be compiled following the above given rules (one start sector).

Only material media are considered, therefore the index of Card A (in the O5R report) is 2.

4. DECK SETUP

When loading the programmes on system tape the arrangement of the binary decks is as follows.

Programme name	Label	Remark
SP100	SPACE	Normal TIMOC deck.
BEGIN	BEGIN	
WPK06/07	WPK067	
RWS	RWS	
Modification cards	CORTIMG	Binary cards produced by the assembly, listed in section 6. ATTENTION: The first binary card of the assembly must be deleted.
9EX203	9EX203	Subroutines output from the Fortran 2, version 2 library.
	9TSH	
	9STH	
	9RER	
	9WER	
	9IOH	
	9IOS	
	9IOU	
	9EXEM	
	9EXIT	
	9TES	
	9SQRT	
GEOM	GEOM	From the GEOM (05R) deck.
JOM4	JOM4	
JOM5	JOM5	
JOM6	JOM6	
JOM7	JOM7	
JOM9	JOM9	
JOM10	JOM10	
JOM13	JOM13	
JOM14	JOM14	
JOM15		
LOC	LOC	
OMJ8	OMJ8	
LOOKZ	LOOKZ	

Programme name	Label	Remark
GPATH	GPATH	New added subroutines. See section 7.
PATH1	PATH1	
STARTN	START	
RNFLS	RAND	
ENTRIES	ENTRY	
WRTP	WRTP	
BVTBF	BVTBF	
GREAD	GREAD	
RSTRT	RSTRT	
JOMIN	JOMIN	From the GEOM (O5R) deck.
JOM11	JOM11	
JOM12	JOM12	
JOM16	JOM16	
JOM17	JOM17	
END	END	New added subroutine. See section 7.
TRANSFER	PTW	Normal programmethat loads programmes on tape.

5. MAP OF COMMON

Address no.	Label	Remark
77461	IG	Medium number (= material index)
60	RGH	Copy of BLZON
57	RGL	
56	X	
55	Y	
54	Z	
53	SINP	
52	COSP	
51	SINT	
50	COST	
47	SGT	
46	FRP	
45	PTHD	See TIMOC
44	PTHX	
43	NRGC	
42	QRET	
41	QOUT	
40	QSEKN	
37	BLR	
36	QSTPT	
35	QTIME	
34	QCOLL	
33	QBLOC	
32	SRG	
31	NBS	No. of start sectors.
30	XSU(8)	Under and
20	XSP(8)	upper limits of the
10	YSU(8)	coordinates of the
77400	YSB(8)	start blocks.
77370	ZSU(8)	
60	ZSB(8)	

Communication between TIMOC and the intermediate subroutines.

Communication inside the intermediate sub-routines.

Address no.	Label	Remark	
50	BLZONS(8)	List of BLZON belonging to the start sectors.	Communication inside the intermediate sub-routines.
40	WTS(8)	List of weights " " " " "	
30	NMEDS(8)	List of media " " " " "	
20	NBSM	The no. of media connected with SMEC.	
17	SMECR(8)	The media connected with SMEC.	
77307	EMPTY(22)	Free	
77261	MARK	See GEOM(O5R)	Communication inside GEOM and between GEOM and the intermediate subroutines.
	ETC.		
77127		Input data of GEOM, read by JOMIN.	

```
*      IF COMBINED WITH THE J5R GEOMETRY ROUTINE GEOM.

*      ************************************************************
*      REDEFINE THE LAST LOCATION OF COMMON
*      ************************************************************
```

BINARY CARD NO. CORTIMG0 **This card should be deleted in the programme deck!**

PROGRAM CARD

```
005230    CMN1  BOOL    5230
005233    CMN2  BOOL    5233
005261    CMN3  BOOL    5261
005571    CMN4  BOOL    5571
005646    CMN5  BOOL    5646
021142    CMN7  BOOL    21142          PLACE FOR AD HOC PROGRAMME
005232    CMN6  BOOL    5232
 05230   FFIPT  ORG     CMN1
 05233   C4     ORG     CMN2
 05261   C2     ORG     CMN3
 05571   FFITX  ORG     CMN4
 05646   C3     ORG     CMN5
 05232   FFIT   ORG     CMN6
```

BINARY CARD NO. CORTIMG1

```
 05232  0020 00 0 21142          TRA     ATW
               21142          ORG     CMN7
```

BINARY CARD NO. CORTIMG2

```
 21142  0634 00 4 05571  ATW    SXA     FFITX,4
 21143  0500 00 0 77127  AADDR  CLA     ADDR
 21144  0771 00 0 00022         ARS     18
 21145 -0760 00 0 00003         SSM
 21146  0400 00 0 21143         ADD     AADDR
 21147  0621 00 0 05230         STA     FFIPT
 21150  0621 00 0 05261         STA     C2
 21151  0621 00 0 05646         STA     C3
 21152  0020 00 0 05233         TRA     C4
*      ************************************************************
*      CONTROL THE STORING AND THE RETRIEVAL OF BLZON.
*      IF CAUSED BY FISSION THE BUFFER HAS BEEN NAMED FBLZON
*      IF CAUSED BY ELP  * SPEC. THE BUFFER HAS BEEN NAMED IBLZON
*      ************************************************************
006052    D1    BOOL    6052           DEF. OF FBLZON
006136    D2    BOOL    6136           DEF. OF IBLZON
025327    D3    BOOL    25327          DEF. OF RGEST(TIMOC)
030755    D4    BOOL    30755          DEF. OF INDIC(TIMOC)
030756    D5    BOOL    30756          FIRST LOC. NOT USED BY THIS PROGRAM
 06052  FBLZON ORG     D1
 06136  IBLZON ORG     D2
 06136  INDIZS ORG     D2
 25327   RGEST ORG     D3
 30755   INDIC ORG     D4
 30755   INDIZ ORG     D4
 30756   FREE  ORG     D5
*      ************************************************************
```

```
                    007243    B1    BOOL    7243          MODIFICATION 1 BEGIN
                    007254    T1    BOOL    7254          MODIFICATION 1 END
                     07254       E1 ORG     T1
                     07243          ORG     B1

BINARY CARD NO. CORTIMG3
     07243   0500 00 0 77441          CLA     QOUT
     07244   0601 00 4 25327          STO     RGFST,4
     07245   0500 00 0 77460          CLA     RGH
     07246   0601 00 4 06052          STO     FBLZON,4
     07247   0020 00 0 07254          TRA     E1
                          *     **********************************************************

                    013372    B2    BOOL    13372         MODIFICATION 2
                    013404    T2    BOOL    13404         MODIFICATION 2
                     13404       E2 ORG     T2
                     13372          ORG     B2

BINARY CARD NO. CORTIMG4
     13372  -0501 00 0 77441          ORA     QOUT
     13373   0601 00 2 30755          STO     INDIC,2
     13374   0500 00 0 77460          CLA     RGH
     13375  -0320 00 0 13400          ANA     MSC10
     13376   0601 00 2 06136          STO     IBLZON,2
     13377   0020 00 0 13404          TRA     E2
     13400 +007777777777       MSC10 OCT     007777777777
                          *     **********************************************************

                    014067    B3    BOOL    14067         MODIFICATION 3
                    014107    T3    BOOL    14107         MODIFICATION 3
                     14107       E3 ORG     T3
                     14067          ORG     B3

BINARY CARD NO. CORTIMG5
     14067   0625 00 0 77441          STT     QOUT
     14070   0621 00 0 77442          STA     QRET
     14071   0500 00 2 06137          CLA     IBLZON 1,2
     14072   0601 00 0 06136          STO     INDIZS
     14073   0601 00 0 77460          STO     RGH
     14074   0020 00 0 14107          TRA     E3
                          *     **********************************************************

                    013554    B4    BOOL    13554         MODIFICATION 4
                     13554          ORG     B4

BINARY CARD NO. OORTIMG6
     13554   0761 00 0 00000          NOP
     13555   0761 00 0 00000          NOP
                          *     **********************************************************
                    014204    B5    BOOL    14204         MODIFICATION 5
                     14204          ORG     B5
```

```
BINARY CARD NO. CORTIMG7
    14204  0761 C0 0 00000          NOP
    14205  0761 00 0 00000          NOP
                          *      **********************************************************************


                    014672     B6    BOOL     14672          MODIFICATION 6
                    014704     T6    BOOL     14704          MODIFICATION 6
                     14704       E6  ORG      T6
                     14672           ORG      B6

BINARY CARD NO. CORTIMG8
    14672 -0501 00 0 77441          ORA      QOUT
    14673  0601 00 0 30755          STO      INDIZ
    14674  0500 00 0 77460          CLA      RGH
    14675 -0320 00 0 13400          ANA      MSC10
    14676  0601 00 0 06136          STO      INDIZS
    14677  0020 00 0 147C4          TRA      E6
                          *      **********************************************************************
                    017000     B7    BOOL     17000          MODIFICATION 7
                    017015     T7    BOOL     17015          MODIFICATION 7
                     17015       E7  ORG      T7
                     17000           ORG      B7

BINARY CARD NO. CORTIMG9
    17000  0600 00 0 77441          STZ      QOUT
    17001  0625 00 0 77441          STT      QOUT
    17002  0500 00 1 06052          CLA      FBLZCN,1
    17003  0601 00 0 77460          STO      RGH
    17004  0020 00 0 17015          TRA      E7
                          *      **********************************************************************
                     77461       RG  COMMON   1
                     77460      RGH  COMMON   1
                     77442           COMMON   13
                     77442     QRET  COMMON   1
                     77441     QOUT  COMMON   1
                     77127           COMMON   201
                     77127     ADDR  COMMON   1
                                     END
```

77126 IS THE LAST LOCATION NOT USED BY THIS PROGRAM
30756 IS THE FIRST LOCATION NOT USED BY THIS PROGRAM

REFERENCES TO DEFINED SYMBOLS

7243	B1	30756, 7243
13372	B2	7250,13372
14067	B3	13401,14067
13554	B4	14075,13554
14204	B5	13556,14204
14672	B6	14206,14672
17000	B7	14700,17000
5261	C2	21150
5646	C3	21151
5233	C4	21152
6052	D1	21153, 6052
6136	D2	21153, 6136
25327	D3	21153,25327
30755	D4	21153,30755
30756	D5	21153,30756
7254	E1	7247
13404	E2	13377
14107	E3	14074
14704	E6	14677
17015	E7	17004
77461	RG	17005
7254	T1	30756, 7254
13404	T2	7250,13404
14107	T3	13401,14107
14704	T6	14206,14704
17015	T7	14700,17015
21142	ATW	5232
77460	RGH	7245,13374,14073,14674,17003,17005
77127	ADDR	21143,17005
5230	CMN1	0, 5230
5233	CMN2	0, 5233
5261	CMN3	0, 5261
5571	CMN4	0, 5571
5646	CMN5	0, 5646
5232	CMN6	0, 5232
21142	CMN7	0,21142
5232	FFIT	
30756	FREE	
77441	QOUT	7243,13372,14067,14672,17000,17001,17005
77442	QRET	14070,17005
21143	AADDR	21146
5230	FFIPT	21147
5571	FFITX	21142
30755	INDIC	13373
30755	INDIZ	14673
13400	MSC10	13375,14675
25327	RGFST	7244
6052	FBLZON	7246,17002
6136	IBLZON	13376,14071
6136	INDIZS	14072,14676

7. PROGRAMME DESCRIPTION

Programme Name: GPATH

Function: This subprogramme connects the calling programme TIMOC and the subroutine PATH1. Depending on whether the result of PATH1 is a crossing or a collision, the return transfer into TIMOC is to the second or first location after the calling instruction, respectively.

Calling programme: TIMOC

Subroutine called: PATH1

Programme Name: PATH1

Function: Controls the communication between TIMOC and GEOM by copying and modifying the input and output data of GEOM from and into the TIMOC COMMON locations respectively. It computes the x, y and z coordinates which the end of the neutron flight would have if the medium of the starting point extended indefinitely. If the medium of the starting point is empty ($\Sigma_t = 0$) the end-of-flight coordinates are replaced by the direction vector components. It controls the QOUT and QRET parameters.

Calling Programme: GPATH

Subroutine called: GEOM

Input:
- X,Y,Z: The coordinates of the starting point of the neutron flight.
- SEKN: A sign which if $\neq 0$ means a new neutron has been started.
- IG: The actual material index.
- RGH: A packed word containing the block and zone numbers of the starting point (copied into BLZON).
- FRP: The number of mean free paths for the next flight.
- COSP, SINP, COST, SINT: The trigonometric functions defining the direction of the neutron.
- SGT: The total cross-section of the actual medium.

Output:
- X,Y,Z: The coordinates of a point where the neutron was entering another medium (crossing) or the end-of-flight coordinates (collision).
- RGH: Now containing the copy of the new BLZON.
- PTHD: The length of flight to the collision point in cm.
- PTHX: The length of flight to the crossing point in cm.
- QCOLL: This sign = 1 if the event was a collision.
- QOUT: } see section 2.3.
- QRET: }
- FRP: The number of mean free paths still available to continue the flight.
- IG: The new material index.

Programme Name: STARTN

Function: Selects at random from a list of given blocks a start block, applying the probability weight given to each block in this list. Next it selects randomly a starting point in the sector of the start block that contains the given medium.

Calling programme: GSTRT (ENTRY).

Subroutines called: JOM14, JOM6, RNFLS.

Output: X,Y,Z: The selected coordinates for a starting point of a neutron.

IG: The material index in the start region.

RGH: A packed word containing the block and zone numbers of the starting point.

In the case of the fixed start point specification in TIMOC only IG and RGH are stored.

Programme Name: RNFLS

Function: Generates a quasi random number between 0 and 1.

Calling Programme: STARTN

Programme Name: RSTRT

Function: Reads the input cards S and T. Next it calculates the boundary coordinates and BLZON parameter of the start blocks, normalizes the weights and checks the start media in the input cards with the media found on the location of the given coordinates.

Calling programme: GREAD

Subroutine called: LOOKZ.

Programme Names: GPRNT — All entries are in one deck labeled ENTRY.
GSTRT
CELL
SURFC
PROJ
NAME
GINP
GEPR
GERJ
GEDS
GMAC

Function: With the exception of GPRNT and GSTRT all dummy entries.

GPRNT calls for WRTP.

GSTRT calls for STARTN.

Programme Name: WRTP
Function: Writes the message "SEE INPUT PRINT OF RWS".
Calling Programme: GSTRT.

Programme Name: BVTBF
Function: A dummy entry to define for TIMOC the first free location for data.

Programme Name: GREAD
Function: Combines TIMOC with the input routines JOMIN and RSTRT. The first free location for data is in the accumulator when the control is transferred to TIMOC.
Calling programme: TIMOC
Subroutines called: JOMIN, RSTRT.

References

(1) TIMOC (Time dependent Monte Carlo code) by H. Rief and H. Kschwendt
EURATOM report EUR 4519 e (1970)

(2) O5R, a General-Purpose Monte Carlo Neutron Transport Code by D.C. Irving e.a.
Oak Ridge National Laboratory ORNL-3622.

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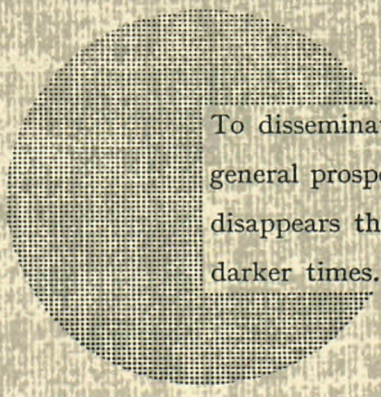

To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

Alfred Nobel

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